Sierra Nevada Network Vital Signs Monitoring Plan

Appendix B: Biology, Ecology, Landscape, and Ecosytem Processes in Sierra Nevada Network Parks

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Linda S. Mutch, Inventory & Monitoring Coordinator
Sierra Nevada Network, Sequoia & Kings Canyon National Parks
47050 Generals Highway
Three Rivers, CA 93271

Meryl Goldin Rose, Ecologist
Sierra Nevada Network Inventory & Monitoring Program
Yosemite Field Station
P.O. Box 700, El Portal, California 95318

Andrea M. Heard
Sierra Nevada Network, Sequoia & Kings Canyon National Parks
47050 Generals Highway
Three Rivers, CA 93271

Rosamonde R. Cook
528 Spruce Street
Riverside, CA 92507

Gary L. Entsminger
Acquired Intelligence, Inc.
23625 V66 Trail
Montrose, CO 81401

With Contributions from:

Tony Caprio, Laura Clor, Annie Esperanza, Sandy Graban, Liz van Mantgem.

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Table of Contents

Figures

Tables

Part I. Biology, Ecology, Landscape, and Ecosytem Processes of Sierra Nevada Parks

Sierra Nevada Network parks lie within the Sierra Nevada, the highest and most continuous mountain range in California. The range runs 692 km from north to south, is up to 113 km wide, and encompasses almost 75,520 sq. km. The range is flanked by California's Central Valley on the west and the arid western edge of the Great Basin on the east (Figure B–1).

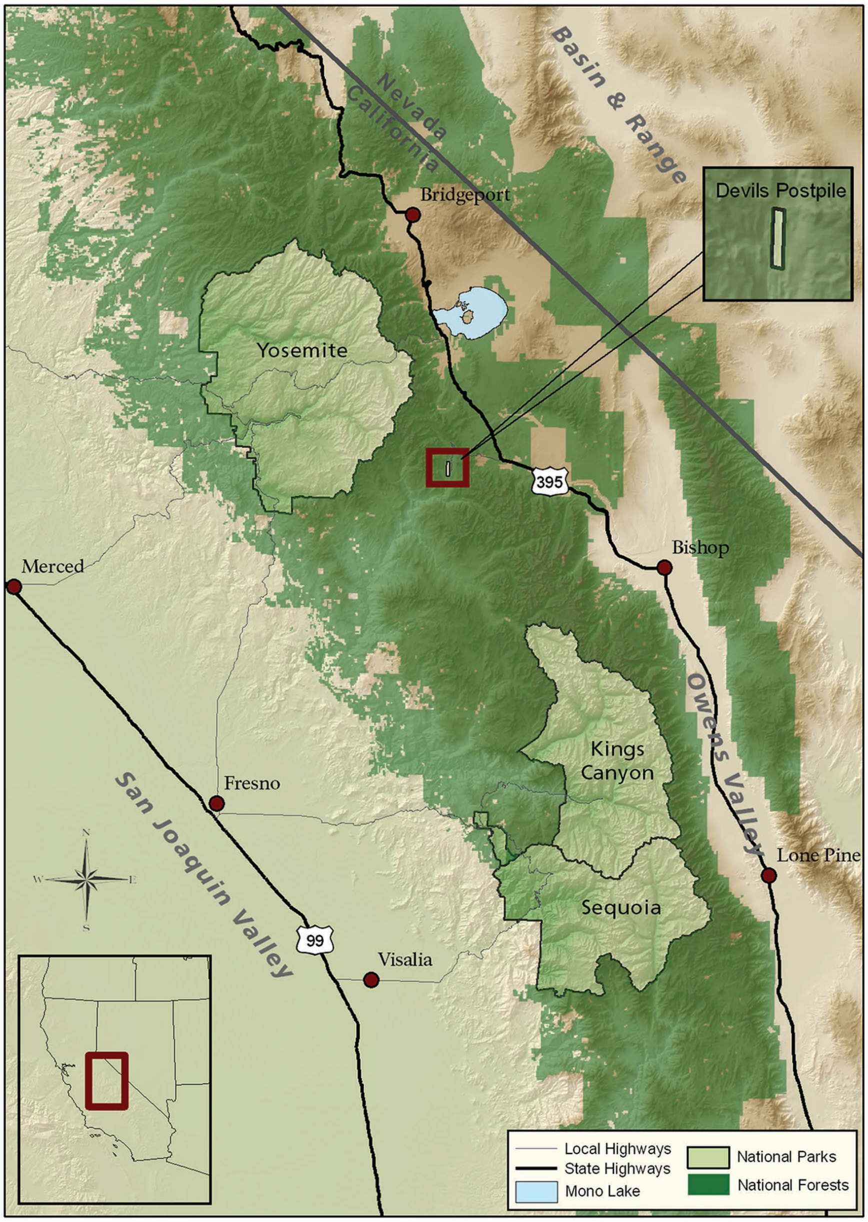
Humans have been part of Sierra Nevada ecosystems for at least 9,000 years B.P. (Roper Wickstrom 1992). Numerous, distinct American Indian groups were widely distributed throughout the region well before settlement by Euramericans in the mid-19th century. Although the record is incomplete, archaeological evidence indicates that, prior to the 1850s, the American Indian population in the Sierra Nevada may have been as large as 90,000 to 100,000 people (Anderson and Moratto 1996).

Settlement patterns and resource use have historically reflected the export value of Sierra Nevada resources as commodities. The foothills became a focus of early attention for "Mother Lode" gold deposits, timber, water, and agriculture. An estimated 150,000-175,000 Euramericans moved into the Sierra Nevada from 1848 to 1860. The population in 1970 was about 300,000, and by 1990, over 650,000 people were living in the Sierra. About 70% of the current population is located on the west-side foothills, with other concentrations in the vicinities of the main Sierran highways. Projections suggest that the Sierra Nevada population will grow between 1.5 and 2.4 million residents by 2040 (SNEP 1996a).

The following sections contain an overview of the physical environment, the important role of fire, biological diversity and the major stressors and management issues for the Sierra Nevada region and parks.

For readers who wish additional information about the larger Sierra Nevada region, see Sierra Nevada Ecosystem Project (SNEP), a detailed report requested by Congress in the Conference Report for Interior and Related Agencies in 1993 Appropriation Act (H.R. 5503), which authorized funds for a "scientific review of the remaining old growth in the national forests of the Sierra Nevada…, and for a study of the entire Sierra Nevada ecosystem by an independent panel of scientists, with expertise in diverse areas related to this issue" (SNEP 1996b). The report is a four-volume scientific assessment by an interdisciplinary team of scientists from land management agencies (primarily National Park Service and US Forest Service), universities, and private consulting groups. SNEP highlights what is known about physical, biological, ecological, social and institutional

Figure B–1. Sierra Nevada Network parks in the context of the larger region: Central Valley and Pacific Ocean to the west, and Great Basin to the east.



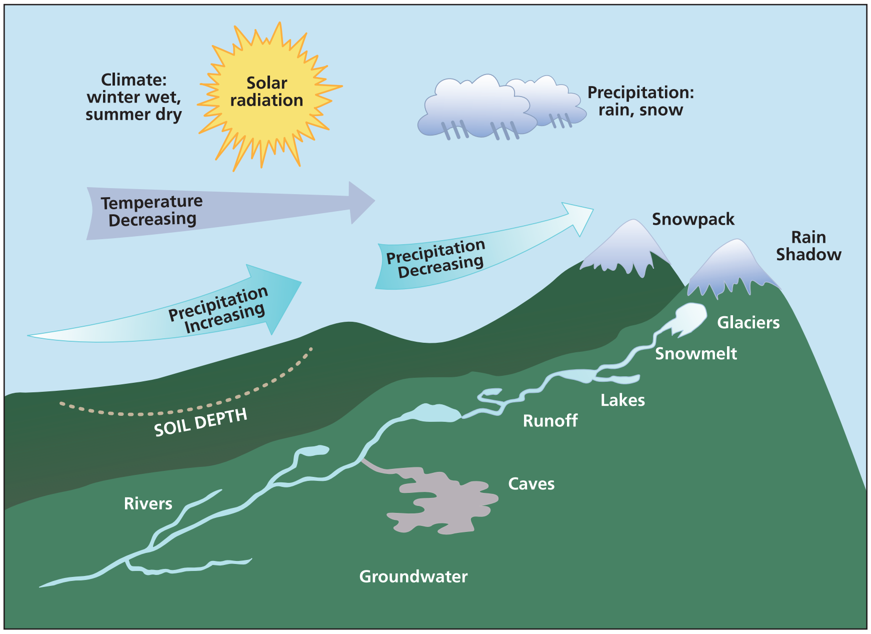


Figure B–2. The Sierra Nevada physical setting illustrates the elevational gradient from the Central Valley and foothills (left side of image), up to the Sierra Nevada crest, and dropping back down more steeply along the east slope (right side of image). Climatic, geologic, and hydrologic processes and features change along this gradient.

conditions for the Sierra Nevada region and presents individual and collective judgments about what this knowledge means for protecting the health and sustainability of Sierra Nevada ecosystems while providing resources to meet human needs.

Physical Setting

The Sierra Nevada is a tilt block asymmetric mountain range with a short, steep east escarpment. The western flank has a longer and gentler slope in Yosemite and the northern Sierra Nevada. Farther south, in Sequoia National Park and elsewhere in the southern Sierra Nevada, the western flank is much steeper, rising from near sea level to 4,818 meters in less than 100 kilometers. This striking elevational gradient characterizes the physical environment in the three large network parks (YOSE, SEQU, KICA) and creates coincident gradients in climate that drive the distribution of plants and animals. Climatic, geologic, and hydrologic processes have dramatic effects in the Sierra Nevada (Figure B–2): concomitantly, changes in these processes have dramatic effects on Sierra Nevada ecosystems.

Climate

Strong climatic gradients develop with changing elevation in the Sierra Nevada, from west to east. Low to mid-elevations have a Mediterranean climate, characterized by hot, dry summers and cool, wet winters. Higher elevations are dominated by a microthermal (or Boreal) climate, characterized by having average temperatures of below -3°C during the coldest month. As a result, a steep temperature gradient parallels the elevation gradient; on average, each 100 m gain in elevation results in a 0.6 C° drop in air temperature. This lapse rate varies locally according to factors such as air speed, relative humidity, slope aspect, insolation, and vegetation cover (Stephenson 1988), but the general pattern holds true as one climbs from the hot lowlands to the alpine crest.

The west slope of the Sierra receives between 50 and 200 cm of rainfall each year, depending on elevation. Above 2100 m on the western slope, about 50% of precipitation falls as snow (Stephenson 1988), creating a significant snowpack in the montane and subalpine elevations. Just as mean temperature decreases with increasing elevation, so does the moisture-holding capacity of air. By the time winter storms reach the alpine, much of the moisture has been lost from the clouds and the amount of snow accumulating on the ground begins to decline with increasing elevation. East of the crest, the mountains create a rain shadow with significantly less moisture falling throughout the season. Precipitation also increases with latitude, due to Pacific jet stream position and subtropical high pressure cells. Across all elevations and latitudes, nearly 70% of precipitation falls from December through March and only about 4% from June through September (Stephenson 1988).

Climatic forces are a major driver of Sierra Nevada ecosystems. Current patterns of vegetation, water dynamics, and animal distribution in the Sierra are determined largely by cumulative effects of past and present climates.

Geology & Soils

The Sierra Nevada batholith is part of a more or less continuous belt of plutonic rocks that extends from the Mojave Desert to northwestern Nevada (Bateman et al. 1963). These granitic magmas intruded into preexisting metasedimentary and metavolcanic country rocks from ~215- 70 million years ago, and were subsequently uplifted and tilted to the west, giving the range its asymmetric geometry with a short, steep east escarpment and a longer and gentler west slope (Whitney 1880, Lindgren 1911, Matthes 1960). Metamorphic units are still present as isolated roof pendants near the Sierra crest (Huber et al. 1989). With the onset of uplift, the erosive power of major streams was intensified due to their increased gradients, resulting in greater rates of incision and rolling hills that gave way to higher relief mountains with deep canyons cutting into the range's west flank (Huber 1987).

On the eastern flank of the mountains, volcanic activity at ~100 thousand years ago sent a lava flow into a valley, now designated Devil's Postpile NM, which cooled uniformly, contracted, and fractured into hexagonal columns. At ~10 thousand years ago, this formation was overridden by glaciers, exposing the columns. Evidence of the glacier—polish and scratches from glacial ice—remains atop the postpile (Clow and Collum 1986).

Several glacial periods in the Sierra Nevada, beginning at ~1 million years ago and lasting until ~10 thousand years ago, periodically covered much of the higher elevations of the Sierra Nevada parks and sent glaciers down many of the valleys (Yount and La Pointe 1997). Glacial ice quarried and transported vast volumes of rubble, which scoured and eroded the landscape. Small quantities of this debris accumulated along the margins of the glaciers and in widely distributed, hummocky piles called moraines. Landforms resulting from glaciation include U-shaped canyons, jagged peaks, rounded domes, waterfalls, and moraines. Granite that has been highly polished by glaciers is common in the parks and provides further evidence of glaciation. The innumerable natural lakes in the high Sierra Nevada are the result of glacial activity forming their basins. These lakes are transitory; eventually they will be filled with sediment and become meadows. Many lakes in the parks already have undergone this transformation (Huber 1987).

Sequoia and Kings Canyon National Parks contain more than 200 named caves (Despain 2003). The caves occur at elevations from 488 to 3,048 m, and include the longest cave in California, Lilburn Cave, with nearly 32 km of surveyed passage. Lilburn is a very complex maze cave with beautiful blue- and white-banded marble. Crystal Cave, developed with lights and trails at the end of the Great Depression, is one of the area's most popular tourist destinations. The caves provide unique habitats for animals, including bats, salamanders, small mammals, and invertebrates, some of which are endemic to specific caves (Despain 2003).

Soil and water chemistry characteristics in the Sierra Nevada are largely geologically controlled. Because the Sierra Nevada is underlain by mostly granitic rocks, soils that derive from these foundations are poorly developed, rocky, and generally low in fertility. Soils are thin due to recent glaciation, but tend to be thicker where not glaciated. In general, soil depth decreases with increasing elevation; deep alluvial soils of the Central Valley give way to shallow, decomposed granites and barren rock outcrops in alpine environments (Taskey 1995).

River basins are often underlain by surficial deposits, which are primarily glacial tills that occur in valley bottoms as lateral and recessional moraines, and are probably derived from the granitic bedrock present at higher elevations (Huber 1987, Bateman 1992). Stream water concentrations of chemical constituents such as cations, alkalinity, and silica tend to be higher in catchments with a high percentage of surficial cover (Clow et al. 1996), reflecting the importance of glacial till in controlling water chemistry. Bedrock geology across the Sierra Nevada is dominated by granitic intrusive rocks of fairly uniform composition (Huber 1987, Bateman 1992); however, slight variations in bedrock composition are reflected in the chemistry of surface waters. For example, according to Clow et al. (1996), streams of Yosemite in the upper Merced River basin that drain granite and light-colored granodiorite terranes have relatively low Ca:Na ratios, while streams that drain dark-colored granodiorites and tonalites tend to have higher ratios. These few preceding examples exhibit how the fundamental ecosystem building blocks of water and soils are inextricably linked to the underlying geology in the Sierra Nevada.

Air Resources

Kings Canyon, Sequoia, and Yosemite National Parks are designated Class I air sheds under the Clean Air Act (1977 amendment). As such, the parks are afforded the greatest degree of air quality protection, and the National Park Service is required to do all it can to ensure that air quality related values are not adversely affected by air pollutants. Devils Postpile National Monument is designated a Class II air shed. There is still a mandate to protect Class II air sheds; however, it is not as stringent compared to Class I air sheds. Despite these designations, air quality in the Sierra Nevada is impaired, threatening natural resources, human health, and visitor experiences *(See section 1.7, Sierra Nevada Ecosystem Stressors in Vital Signs Monitoring Plan, and also Appendix C)*.

In addition to air quality, Sierra Nevada parks contain other air resources, including night sky and natural soundscapes that are intrinsic elements of the environment (just as water and wildlife are intrinsic values). Night sky visibility is an important aesthetic value of wilderness and its protection has been added to the responsibilities of National Park Service managers. Light pollution is not confined to cities. Excessive glare, urban sky glow, and poorly designed lighting threaten dark skies in the Sierra Nevada. Natural soundscapes are inherent components of “the scenery and the natural and historic objects and the wild life” and are protected by the National Park Service’s Organic Act. They are vital to the natural functioning of many parks and may provide valuable indicators of ecosystem condition (National Park Service 2001).

Water Resources

SIEN parks span seven major watersheds: Tuolumne, Merced, San Joaquin, Kings, Kaweah, Kern and Tule (Figure B–3). Runoff from these watersheds drains into the San Francisco Bay/Sacramento–San Joaquin Delta in the north and the Tulare Lake Basin in the south. Yosemite, Sequoia, and Kings Canyon parks contain most of the headwater streams. Devils Postpile National Monument is located within the upper Middle Fork of the San Joaquin watershed. The headwaters of the Middle Fork of the San Joaquin begin 14.1 km upstream of the monument at Thousand Island Lake. The watershed area above the monument is managed by Inyo National Forest. The Sierra Nevada parks protect a diversity of water resources, including over 4,500 lakes and ponds, thousands of kilometers of rivers and streams, seeps, wet meadows, waterfalls, hot springs, mineral springs and karst springs.

Water dynamics in the Sierra Nevada are a critical component of both the parks’ ecosystems and the larger California water infrastructure. The snow pack acts as a temporary reservoir, storing water that will be released during the warmer and drier months. Peak runoff typically occurs late May to early June. Water is captured and stored for summer use in a series of reservoirs in the Sierra foothills. Reservoirs are primarily located downstream of park boundaries, although there are exceptions, including Hetch Hetchy and Lake Eleanor in Yosemite and four small dams in Sequoia.

Sierra Nevada ecosystems produce approximately $2,200,000,000 in annual revenue. Water accounts for more than 60% of these dollars (SNEP 1996b). Primary uses include irrigated agriculture, domestic water supplies, hydroelectric power, recreation and tourism. Water resources and associated aquatic and riparian habitats also have high ecological value. Approximately 21% of vertebrates and 17% of plants in the Sierra Nevada are associated with aquatic habitats (SNEP 1996b).

The California Water Resources Control Board (WRCB) and nine Regional Water

Quality Control Boards (RWQCB) are responsible for protecting and enhancing California's water resources under the Porter-Cologne Water Quality Control Act. Each RWQCB adopts Basin Plans, which contain beneficial use designations, water quality objectives, and implementation programs.

Sierra Nevada Network parks fall under jurisdiction of the Central Valley RWQCB and have waters contained in both the Sacramento-San Joaquin and Tulare Lake basins. Under sections 305(b) and 303(d) of the Clean Water Act, California must assess overall health of the state's waters and identify waters that are not attaining water quality standards. The State must compile water quality limited waters in a 303(d) list and initiate a process to bring listed waters back into compliance. Sierra Nevada Network parks do not contain any 303(d) listed waters (State Water Resources Control Board 2002). The State also has authority to designate waters as Outstanding Natural Resource Waters—the highest level of protection afforded to a water body under the Clean Water Act. Sierra Nevada Network parks do not have any Outstanding Natural Resource Waters, but waters in national parks are strong candidates for this designation.

There are four Wild and Scenic Rivers in the parks—the Middle and South Forks of the Kings River (98.5 km) and the North Fork of the Kern River (46.5 km) in Sequoia and Kings Canyon, and the Merced (130.0 km) and Tuolumne (87.0 km) rivers in Yosemite.

The Sierra Nevada Ecosystem Project (SNEP) identified aquatic and riparian systems as the most altered and impaired habitats in the Sierra Nevada (SNEP 1996b). Primary reasons for deterioration are changes in flow regimes, disturbances from land use practices, and introduction of non-native organisms. Despite these impacts on aquatic and riparian habitats, basic hydrologic processes and water quality remain in relatively good condition (Kattelmann 1996). Hydrologic modifications and degraded water quality are of greatest concern downstream of the parks in foothill reservoirs and the Central Valley. Devils Postpile, Sequoia, Kings Canyon and Yosemite protect some of the least altered aquatic ecosystems in the Sierra Nevada.

Figure B–3. Watersheds in Sierra Nevada Network parks.

See Appendix D for a more detailed description of Sierra Nevada water resources.

Fire: A Key Process

Fire has played a pivotal role in shaping ecosystems and landscapes in the Sierra Nevada for many millennia (Davis and Moratto 1988, Smith and Anderson 1992, SNEP 1996a, Anderson and Smith 1997). It affects numerous aspects of ecosystem dynamics such as soil and nutrient cycling, decomposition, succession, vegetation structure and composition, biodiversity, insect outbreaks, and hydrology (Kilgore 1973, SNEP 1996a). Historically, fire frequency, size, intensity, and severity varied spatially and temporally across the landscape depending on number of ignitions, climate, elevation, topography, vegetation, fuels, and edaphic conditions (Skinner and Chang 1996). Fires were common, often burning for months and reaching large sizes.

Periodic fires performed many ecological functions within Sierran ecosystems prior to Euramerican settlement. Frequent surface fires in many vegetation types minimized fuel accumulation while their variable nature helped create diverse landscapes and forest conditions (Stephenson et al. 1991, SNEP 1996a). Fires tended to be low to moderately severe, with highseverity portions (intense enough to kill most large trees) generally restricted to localized areas of a fraction of an acre to a few acres. Extensive research in mixed-conifer forests has shown that low intensity surface fires were common and tended to keep the forests open (Biswell 1961, Hartesveldt and Harvey 1967, Weaver 1967, Kilgore 1971, 1972, Weaver 1974, Harvey et al. 1980).

Many species and most plant communities show clear evidence of adaptation to recurring fire, indicating that fire occurred regularly and frequently, particularly in the chaparral and mixedconifer communities, where many plant species have life history attributes tied to fire for reproduction or as a means of competing with other biota. Fire damaged or killed some plants, setting the stage for regeneration and vegetation succession. Many plants evolved fire-adapted traits, such as thick bark, and fire-stimulated flowering, sprouting, seed release, and/or germination (Chang 1996). Fire influenced soil and forest floor processes and organisms by consuming organic matter and inducing thermal and chemical changes. It also affected the dynamics of biomass accumulation and nutrient cycling at a variety of spatial scales. These effects in turn influenced habitats and the distribution and occurrence of many species.

Fire regimes are defined according to specific variables including frequency, severity, season, duration, magnitude, spatial distribution, and type of fire (Gill 1975, Heinselman 1981). These characteristics may vary through time and across the landscape in response to climatic variation, number of lightning ignitions, topography, vegetation, historic events, and cultural practices (SNEP 1996a). Fire regime types for major Sierra Nevada plant communities vary from shortinterval, low-intensity surface fires in ponderosa pine and blue oak woodland to long-interval, variable intensity fires that occur in lodgepole pine forests and include numerous other fire regimes in diverse vegetation types of the Sierra Nevada.

Variation in fir frequency exists locally and at large scales, and is affected by site productivity, potential for ignition, and other factors. General patterns of pre-Euramerican fire frequencies are apparent at several scales in the parks. Differences in average fire frequency are also apparent in different vegetation types (Table B- 1 and Figure B- 4). On the west slope of the Sierra, frequencies were reconstructed using fire-scarred trees. Data show an inverse relationship between number of fires and elevation (Caprio and Swetnam 1995, Swetnam et al. 1998, Caprio 2000).

Short-term climatic variation had a significant impact on past burn patterns and fire severity. Historically, on the west slope of the Sierra Nevada, specific fire years have been identified (years in which fires have been recorded at sites throughout the southern Sierra Nevada). These usually occurred during dry years (Brown et al. 1992, Swetnam et al. 1992, Swetnam 1993, Swetnam et al. 1998). Analysis of millennial-length fire histories from giant sequoias also document long-term variation (1,000-2,000 years) in the fire regime associated with climatic fluctuations (Swetnam 1993). These data suggest more frequent but smaller fires occurred during the Medieval Warm Period (A.D. 1000 - 1300) and fewer larger fires during cooler periods (A.D. 500 - 1000 and after A.D. 1300). These fluctuations indicate that characteristics of fire regimes are dynamic over long time periods.

Although fire regime characteristics may vary through time and across the landscape, from the late 1890s through the 1960s, Sierra Nevada park and

Table B- 1. Mean and maximum fire return intervals for major vegetation classes in Sierra Nevada Parks. The table also includes quality of the knowledge used to calculate or estimate fire return intervals and sources used to obtain this information.

VEGETATION CLASS	MEAN (MAX) FIRE INTERVAL-YEARS	KNOWLEDGE	REFERENCE
Very Low Fire Frequency			
Lodgepole Pine	102 (163)	v. poor	5, 6,18
Subalpine Conifer	187 (508)	poor	5, 9
Low Fire Frequency			
Red Fir Mixed-conifer	30 (50)	poor	1, 4, 5
Xeric Mixed-conifer	30 (50)	v. poor	5, 7, 8, 17
Montane Chaparral	30 (75)	estimated	12
Meadow	40 (65)	estimated	8
Foothills Chaparral	30 (60)	estimated	12
Moderate Fire Frequency			
Foothills Hardwood & Grassland	10 (17)	v. poor	5, 10, 11
Mid-elevation Hardwood	7 (23)	v. poor	3, 19
High Fire Frequency			
White Fir Mixed-conifer	10 (16)	good	1, 2
Giant Sequoia	10 (16)	good	13, 14, 15
High Fire Frequency			
Ponderosa Mixed-conifer	4 (6)	good	1, 2, 3, 16, 17

Notes: Data are prior to 1860 (1870 for subalpine conifer). Primary source(s) also listed in References. Fire frequency regime classes for each major vegetation class are based on mean maximum fire-return intervals (i.e., average of the longest fire-return intervals). Frequency classes were used to reconstruct fire frequency regimes spatially across the parks.

national forest personnel attempted to suppress all fires, and these efforts met with a fair degree of success. Consequently, numerous ecosystems that had evolved with frequent fires have since experienced prolonged periods without fire (Swetnam et al. 1992, Swetnam 1993, Caprio and Graber 2000, Caprio et al. 2002, Caprio and Lineback 2002). This change in fire regime has severely modified ecosystems. See Appendix F, *"Conceptual Models"*—Stressors.

1(Caprio and Swetnam 1993, 1994, Caprio and Swetnam 1995); 2 (Kilgore and Taylor 1979); 3 (Stephens 1997) unpublished data in (Skinner and Chang 1996); 4 (Pitcher 1981, 1987); 5 Caprio unpublished data 2000 ; 6 (Keifer 1991); 7 Taylor, unpublished data in (Skinner and Chang 1996); 8 Skinner, unpublished data in Skinner and Chang 1996; 9 Caprio, Mutch, and Stephenson unpublished data ; 10 (Mensing 1992); 11 (McClaren and Bartolome 1989); 12 (SNEP 1996a); 13 (Swetnam et al. 1990); 14 (Swetnam et al. 1992); 15 (Swetnam 1993); 16 (Warner 1980); 17 (McBride and Jacobs 1980); 18 (Sheppard 1984); 19 (Stephens 1997).

Plant and Animal Diversity

The striking elevational gradient and topographic variability in the Sierra Nevada result in a high diversity of habitats for plants and animals. Sequoia, Kings Canyon and Yosemite National Parks, the largest and least fragmented habitat blocks in the Sierra Nevada, are recognized for their importance in protecting the long-term survival of certain species and the overall biodiversity of vegetation and wildlife in the region (SNEP 1996a).

The parks' vegetation can be categorized broadly into the following vegetation zones: oak woodland, chaparral scrubland, lower montane, upper montane, subalpine, and alpine. Vegetation changes dramatically along west-east elevation gradients from the lowest elevation oak woodlands up to ancient foxtail pines and western juniper, krumholz whitebark pine, and alpine perennial herbs at the highest elevations.

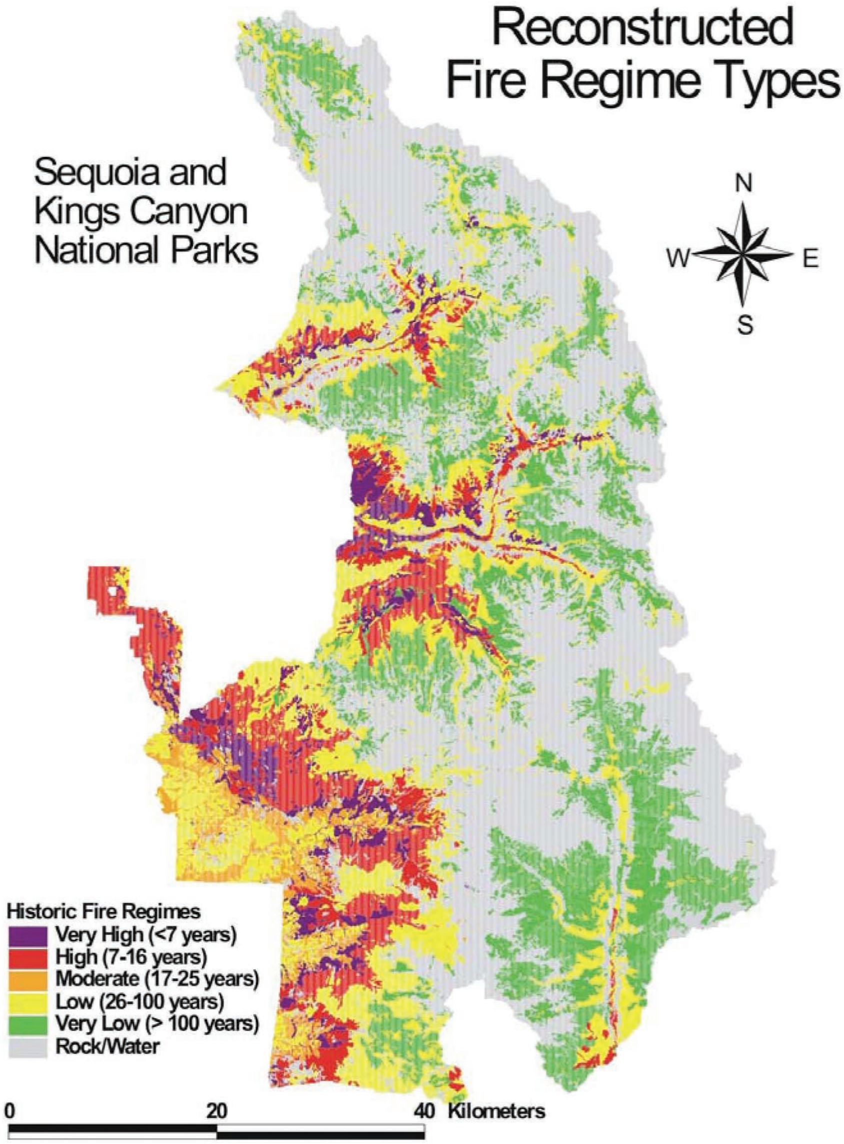


Figure B–4. Mean fire-return intervals (i.e., historic fire regimes), or mean time between fires, for different vegetation or cover classes in Sequoia and Kings Canyon National Parks (Caprio and Lineback 2002). Sources used to construct these fire regime types are summarized above in Table 1-3. A similar map exists for Yosemite National Park (van Wagtendonk et al. 2002).

While the parks' eastern boundaries are along the Sierra Nevada crest, some areas have plant communities showing a mix of west and east slope affinities, such as Devils Postpile National Monument (Arnett and Haultain 2004). Sparse forests on the upper east slope of the Sierra Nevada grade into semi-arid Great Basin scrublands in the mountains' rain shadow (Figure B- 5).

In its entirety, the Sierra Nevada region supports over 3,500 native vascular plant species, comprising half of the approximately 7,000 vascular plant species in California. Sierra Nevada parks support more than 20% of this California total.

All parks have had vegetation inventories done that are of value as baseline data for long-term monitoring. These include vegetation maps, Natural Resource Inventories in the 1990s in Sequoia, Kings Canyon, and Yosemite (Graber et al. 1993), a vascular plant inventory in Devils Postpile (Arnett and Haultain 2004), and rare plant surveys for individual park units (in progress, and Moore 2006).

In its entirety, the Sierra Nevada region supports over 3,500 native vascular plant species, comprising half of the approximately 7,000 vascular plant species in California. Sierra Nevada parks support more than 20% of this California total. DEPO data (Arnett and Haultain 2004), SEKI data (Norris and Brennan 1982, Stokes 2003); YOSE data (Botti 2001, Gerlach et al. 2002, Johnson 2003, Moore 2003, Stokes 2003)(Table B- 2).

Bryophyte collections have been made in all Network parks (Steen 1988, Norris and Shevock 2004b, a, Shevock In progress). Surveys have documented 350 moss species in the southern Sierra Nevada region; 300+ species are estimated to occur in the central Sierra Nevada region (Shevock 2002). Lichen surveys have been limited (Smith 1980, Wetmore 1986); however, estimates suggest approximately 250 macrolichen and a similar number of crustose species could occur in Sierra Nevada parks (Neitlich 2004).

Table B- 3 lists vertebrate species documented in Sierra Nevada parks. The Sierra Nevada range includes about two-thirds of the bird and mammal species and about half the amphibians and reptiles in the state of California (Graber 1996), and supports over 280 native vertebrates, including fishes. Approximately 300 terrestrial vertebrate species use the Sierra Nevada as a significant part of their range; another 100 species use the Sierra Nevada as a minor part of more extensive home ranges: of 401 terrestrial species (not including fishes) documented for the Sierra Nevada, 232 are birds, 112 are mammals, 32 are reptiles, and 25 are amphibians (Graber 1996).

The foothills of the parks become

increasingly important as similar areas outside park boundaries succumb to heavy grazing and residential development. Most plant communities in the parks are comprised of native plant species, but foothill woodlands are dominated by non-native annual grasses introduced to California during the mid 19th century. Low elevation chaparral communities are dominated by dense thickets of thick-leaved shrubs. Many of these shrubs exhibit adaptations to fire and drought, both of which strongly influence the foothill environment. Particularly important resources to wildlife in these areas include blue oak (*Quercus douglasii*) acorns and chaparral shrub berries (especially manzanita) as well as other forage and cover.

Sierra Nevada montane forests form some of the most extensive stands of old growth mixed-species coniferous forest remaining in the United States. These mixed-coniferous forests support a remarkable diversity of tree species: ponderosa pine (*Pinus ponderosa*), incense-cedar (*Calocedrus decurrens*), white fir (**Abies concolor**), red fir (*Abies magnifica*), sugar pine (*Pinus lambertiana*), and giant sequoia (*Sequoiadendron giganteum*).

Giant sequoias occur naturally only in the Sierra Nevada, where they are found in approximately 75 separate groves. The 42 named groves in Kings Canyon, Sequoia, and Yosemite contain roughly one-third of all naturally occurring sequoia trees.

As one moves higher in elevation to the upper montane zone, mixed-coniferous forest is replaced by nearly pure stands of red fir and lodgepole pine (*Pinus contorta*), with some Jeffrey pine (*Pinus jeffreyi*), and western juniper (*Juniperus occidentalis*). Lodgepole pines tend to occur in moist lowlands, as well as in drier sites on benches and ridges. Animal diversity is at a maximum in lower and upper montane forest habitats, due to the relatively mild climate, and the mixture of habitat types and plant species present.

In the subalpine zone, western white pine (*Pinus monticola*), mountain hemlock (*Tsuga mertensiana*), lodgepole pine (*Pinus contorta*), foxtail pine (*Pinus balfouriana*), and stands of whitebark pine (*Pinus albicaulis*) intermix with subalpine meadows and lakes. In rocky alpine areas, where very short growing seasons and harsh winter conditions exist, trees give way to low-growing, perennial herbs. Plants often form ground-hugging mats or hummocks as a result of warmer temperatures closer to the surface. Winter snow provides insulation from extreme low temperatures and desiccating winds. Although exposed granite outcroppings, talus slopes, and boulder fields dominate this zone, these rocky habitats support a surprisingly rich flora.

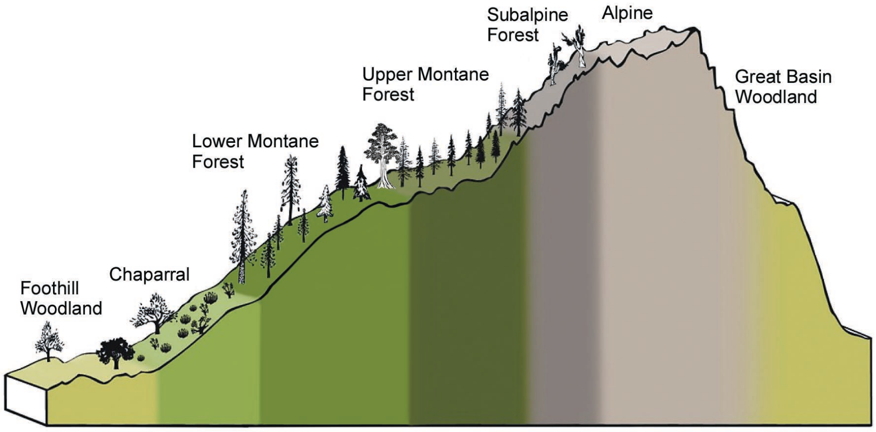
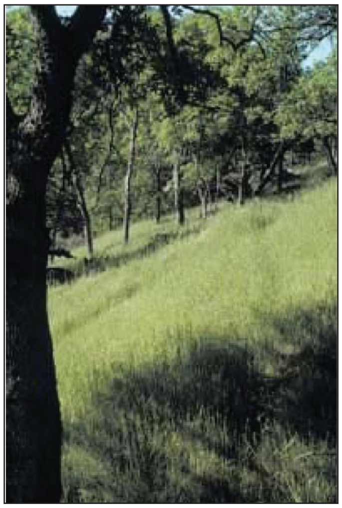


Figure B–5. Sierra Nevada vegetation zones along its west-to-east elevation gradient, from the Central Valley and foothills, up to the Sierra Nevada crest, and down its east slope. The diverse topography results in high diversity of plants and animals. Illustration by Justin Hofman.


Blue oak woodland

Clark's Nutcrackers are specialized for feeding on large pine seeds. Its behavior, annual cycle, and even its morphology are closely tied to this diet and thereby closely tied to subalpine white pine forests. Alpine talus fields are inhabited by pikas, marmots, voles, mice, shrews; endangered toads, many diverse invertebrate assemblages, and various other types of animals. Scattered bands of Sierra bighorn sheep (a federally endangered species), can still be found in some of the highest and most remote areas along the crest.

Meadows and wetlands, while occupying a small fraction of the land area in the Sierra Nevada, are a key ecosystem element in the Sierra Nevada. Meadows are extremely productive ecosystems, and provide critical breeding and

Table B-2. Vascular plant species documented in Sierra Nevada parks.

	DEPO	SEKI	YOSE
Vascular Plant Taxa	380	1,494	1,561
Special Status spp.	0	138	160
Non-native spp.	8	215[1]	160[2]

Data source: NPSpecies (https://science1.nature.nps.gov)
[1] Of these, 100 species do not occur in YOSE.
[2] Of these, 45 species do not occur in SEKI.

Table B-3. Vertebrate species documented in Sierra Nevada parks.

	DEPO	SEKI	YOSE
Birds	118	220	283
Mammals	35	91	88
Amphibians	1	13	13
Reptiles	8	26	23
Fishes	5	19	11

Data source: Data source: NPSpecies (https://science1.nature.nps.gov)

Red fir forest

foraging habitat for a suite of animal species in the Sierra Nevada. Recent work demonstrated the importance of Sierra Nevada meadows as breeding grounds for invertebrates, which form the energetic basis of many food chains (Holmquist and Schmidt-Gengenbach 2005). Many insects breed in meadows, and then disperse into adjacent forests and woodlands as the season progresses, where they are important as food sources and as pollinators. Dozens of bird species, including the federally endangered Willow Flycatcher and the state-listed Great Grey Owl, use meadows for foraging, nesting, or both. Mule deer take advantage of the cover provided by montane meadow vegetation by hiding their fawns under the dense herbaceous canopy. Small mammals, such as ground squirrels, pocket gophers, and voles, feed on both above and below ground meadow vegetation. Animals such as frogs, toads, and shrews frequent the moist vegetation edging stream channels.

Aquatic systems (lakes, ponds, streams and rivers) are some of the most biologically impaired systems in the Sierra Nevada. While altered hydrology (diversions, dams) plays a lesser role impacting aquatic life in the parks compared to outside the parks, they are locally important in some developed areas and at Hetch-Hetchy Reservoir in Yosemite. The introductions of nonnative fish to Sierra Nevada lakes and bull frogs to lower elevation lakes and stream courses have had devastating effects on native biota. Foothill yellow-legged frogs are extirpated, and mountain yellow-legged frogs and Yosemite toad are warranted (but currently precluded) for federal listing as endangered. In addition to feeding on tadpoles, non-native fish have altered invertebrate community composition (Stoddard 1987, Matthews et al. 2002), affecting food sources for other animals such as aquatic snakes and Pacific tree frogs (Matthews et al. 2002) and birds (Knapp et al. 2005).

The parks support a large number of special status, rare, or endemic species (NPSpecies (https://science1.nature.nps.gov). Rare local geologic formations and the unique soils derived from them have led to the evolution of ensembles of plant species restricted to these habitats. These include limestone outcrops in Sequoia and Kings Canyon National Parks and a unique contact zone of metamorphic and granitic rock in the El Portal area of Yosemite National Park,

where several state-listed taxa are found (Moore 2003). Karst environments have recently been shown to harbor assemblages of rare and endemic invertebrates (Despain 2003, Krejca in progress) as well as providing roosting sites for bat colonies. Seventeen species of bats are documented for Sierra Nevada parks, nine of which are either Federal Species of Concern or California Species of Special Concern (Pierson et al. 2001, Pierson and Rainey 2003).

While Sierra Nevada parks offer important protected habitats for a diverse assemblage of plants and animals, from direct pressures of habitat fragmentation and use (e.g., development, logging, mining, extensive water diversions, and other human impacts), they do not protect park resources from the larger-scale stressors of air anthropogenic climate change, air pollution, altered fire regimes, and invasive non-native species.

Devils Postpile National Monument

Purpose and Significance

Devils Postpile National Monument was established to preserve "the natural formations known as the Devils Postpile and Rainbow Falls" for both scientific interest and for public inspiration and interpretation (NPS 1982). Devils Postpile is a dramatic mass of columnar-jointed basalt—the remnants of lava that flowed down the valley of the Middle Fork San Joaquin River less than 100,000 years ago. Approximately 20,000 years ago, a glacier overrode the fractured lava mass, exposing a wall of columns 18 meters high and resembling a giant pipe organ. Rainbow Falls, along the Middle Fork of the San Joaquin River, is a spectacular waterfall that drops 31 m (101 feet) over a volcanic cliff.

Yosemite National Park once administered the Devils Postpile area. In 1905, more than 1,295 square kilometers (500 square miles) were withdrawn from Yosemite National Park in the Minaret Range and the Devils Postpile area and returned to public domain. Only 324 hectares (800 acres) were returned to protected status as Devils Postpile National Monument in 1911 by Presidential Proclamation No. 1166 (under President William Howard Taft). Please see Appendix A for the citation which contains additional details about this proclamation.

Devils Postpile National Monument is located high on the western slope of the Sierra Nevada in Madera County, California, near the headwaters of the Middle Fork of the San Joaquin River (Figure B- 6). Elevations within Devils Postpile range from 2,200 m to 2,500 m (7200-8200 feet). It is surrounded on all sides by the Inyo National Forest, and so comprises a small natural area within a much larger contiguous complex of federal public lands extending over a vast area of the eastern and western slopes of the Sierra Nevada range. Three-quarters of Devils Postpile is included within Ansel Adams Wilderness; this Wilderness extends into Inyo National Forest lands west of Devils Postpile. Ten kilometers (6 miles) to the east, and closely allied economically, is the resort town of Mammoth Lakes and the Mammoth Mountain ski complex.

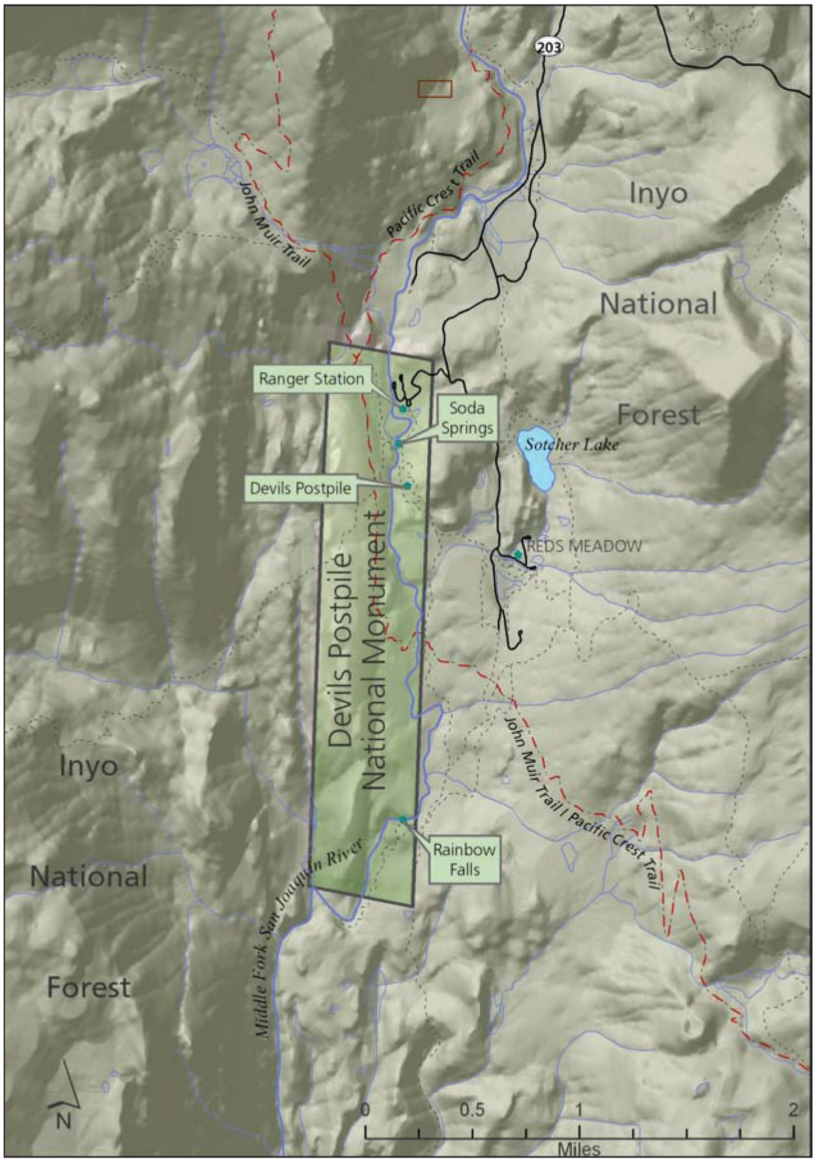


Figure B- 6. Devils Postpile National Monument and surrounding area.

Description of Resource Values

A country of wonderful contrasts.
Hot desertsbounded by snow-laden mountains, cinders and
ashes scattered on glacier-polished pavements,
frost and fire working together in the making of beauty.

–John Muir

As is evident from the basalt columns of Devils Postpile National Monument and glacial polish on the tops of the "postpile columns", the landscape of Devils Postpile National Monument was shaped by volcanism and ice. While glaciers are long gone from the Middle Fork of the San Joaquin drainage, volcanic influence is still strong within the Devils Postpile/ Mammoth Lakes region. The region's soils have high concentrations of ash and tephra, and it is difficult to locate an area within the Devils Postpile not covered by pumice. The pumice indicates post-glacial volcanic activity in the Inyo/ Mono Craters and Long Valley Caldera complex, and it plays an important role in the area's phytogeography and vegetation development.

On slopes underlain by basalt and andesite, where the water table is low and percolation is high, a sparse conifer forest typically exists. Here, pines and firs contribute little organic matter towards extensive soil formation. Instead, the soils remain barren with a paucity of litter and insufficient moisture to enhance soil formation. It is common, on steeper slopes, to see bare rock with few plants. What plants exist often creep downhill with the soil, further inhibiting soil development.

There continues to be volcanic activity in the Long Valley area, just west of Devils Postpile (Huber and Eckhardt 2002):

- Carbon dioxide gas has recently killed many trees at adjacent Mammoth Mountain
- Swarms of earthquakes occurred in the 1980s and 1990s, several of which dislodged postpile column pieces with Devils Postpile National Monument
- Numerous hotsprings are present in the region
- Pumice is young and widespread.

Further, future volcanic activity has the potential to dramatically change the landscape in and surrounding Devils Postpile National Monument. Based on the frequency of eruptions along the Mono-Inyo Crates volcanic chain in the past 5,000 years, the probability of an eruption occurring in any given year is somewhat less than one percent per year or roughly one chance in a few hundred in any given year. This is comparable to the annual chance of a magnitude 8 earthquake (like the Great 1906 San Francisco Earthquake) along the San Andreas Fault in coastal California or of an eruption from one of the more active Cascade Range volcanoes in the Pacific Northwest, such as Mount Rainier in Washington or Mount Shasta in California.

Increased volcanic unrest (including earthquake swarms, ground deformation, and CO_2 gas emissions) in the Long Valley area since 1980 increases the chance of an eruption occurring in the near future, but scientists still lack adequate data to reliably calculate by how much. Volcanic unrest in some other large volcanic systems has persisted for decades or even centuries without leading to an eruption. But since volcanic unrest can escalate to an eruption quickly–in a few weeks, days, or less–USGS scientists continue to monitor the activity closely (http://lvo.wr.usgs.gov/hazards/index.html).

The Middle Fork of the San Joaquin River, which flows through Devils Postpile, is a Wild Trout River. Although the river was designated a 'Wild Trout River' due to its trout populations, highly valued by the recreational fishing community, none of the fish species are native to the river.

The river changes in character many times throughout its journey through Devils Postpile: from a series of broad low-gradient meanders, to scattered pools and fastflowing rapids, cascades, and falls. South of Devils Postpile, the river continues on to race through a narrow granite gorge south of "Lost Camp" and towards Mammoth Pool (the first man-made obstruction on the San Joaquin River). Three small creeks enter the river within or near Devils Postpile National Monument: King Creek, Boundary Creek, and an unnamed creek from Red's Meadow (to the east).

Although the San Joaquin River drains the length of Devils Postpile into the San Joaquin Valley to the west, the Ritter Range west of Devils Postpile is higher in elevation. As a consequence, biological communities contained within have east-slope as well as westslope affinities. The principal vegetation is montane forest, mostly dominated by red fir or lodgepole pine. Along the San Joaquin River, typical montane riparian vegetation dominates, represented by quaking aspen, black cottonwood, alder, and willows. A recent vascular plant inventory of Devils Postpile documented 360 taxa, a 113 percent increase from the 169 taxa documented previously (Arnett and Haultain 2004).

A number of meadows of various subtypes can be located within Devils Postpile. Dry meadows, where seeps or intermittent drainages occur, form shallow meadows occupied by sedges and grasses. In dry years these may not even "green up" after the snow melt. A few larger meadows occur in the southern monument region that are regularly wet and occupied by sedges, mannagrass, wildryes and other grasses. Some of these southern meadows are bordered with quaking aspen.

Soda Springs Meadow is the largest meadow within Devils Postpile. The large meadow is divided by the San Joaquin River and appears to be formed by classic fluvial events. The soda spring for which this meadow is named is at the southern edge of the meadow.

Totally submerged in the June snowmelt, the soda spring gradually becomes more accessible by July. Iron in the water oxidizes to reddish-brown and clearly marks the spring's location. The spring provides a continuous flow of carbonated water throughout the year.

A total of 143 vertebrates have been documented for Devils Postpile (Pierson and Rainey 2002, Gates and Heath 2003, Siegel and Wilkerson 2003, Werner 2004). The animals most frequently observed are birds, small diurnal mammals, and invertebrates. The most frequently seen birds include the Steller's jay, the western tanager, dark-eyed juncos, and hairy woodpeckers. Common mammals within Devils Postpile include the golden mantled ground squirrel, the lodgepole chipmunk, chickaree, and Belding ground squirrels. Porcupines, coyotes, long-tailed weasels, martins, and marmots are occasionally sighted. Mule deer visit Soda Springs Meadow in the evening and early morning hours. Black bears are frequently seen within Devils Postpile boundaries. During August of 2001, a survey of bats was conducted and ten species of bats were newly documented (Pierson and Rainey 2002), six of which are species of special concern.

Because of the cold climate, there are few known species of reptiles and amphibians within Devils Postpile. The Middle Fork of the San Joaquin has four nonnative species of trout, golden trout, rainbow trout, brown trout and brook trout. Many places throughout the Sierra Nevada, including Starkweather and Sotcher Lakes in the Reds Meadows area, are stocked with fish. Devils Postpile has not been stocked with fish since 1995.

The vegetation and wildlife in Devils Postpile are adapted to periodic fire, and evidence of past fires can be found in charcoal and fire scars left on some trees. Fire history and forest age structure studies are currently being conducted (Caprio, in progress). Fire history studies in similar forests in other areas of the Sierra Nevada have shown fires in lodgepole pine forests occurred an average of every 150 years and more frequently in lower elevation mixed conifer forests. The Rainbow Fire burned approximately two-thirds of Devils Postpile in 1992; the most severe burning occurred in the southeast portion. In some areas, tree mortality was high and seedlings have not re-established due to long distances to living trees. In other areas the fire crept along the forest floor, occasionally burning into trees—in these areas, re-establishment of seedlings has been more rapid.

Evidence of prehistoric human use of Devils Pospile has been documented, with several prehistoric sites identified based on the presence of tools, points, and chips. It is considered likely that this area was a locale for seasonal hunting and fishing camps used by Northern Paiute and/or Northfork Mono groups. However, the archeological sites are modest in size. Materials and analyses conducted thus far have not provided the basis for definitive conclusions about the people using the area and the nature of their use.

Historic uses of the area date from the 19th century. A toll road known as the French Trail, was developed in 1879-80 to connect the mining enterprises at Mammoth to the east with the Central Valley to the west. It passed through Reds Meadow, crossed the river and then continued up King Creek. Miners are also thought to have maintained camps in the area at this time and worked nearby mines. Some evidence also suggests late 19th century sheepherder camps within Devils Postpile. The remnants of "Postpile Joe's" trapper cabin dating from the early 20th century can still be seen.

An archeological survey within Devils Postpile was conducted in 1994, following the Rainbow fire. All existing structures, including the rustic ranger station, have been evaluated for historic significance, but were found not eligible for the National Register.

Visitation

The primary period of public use for the area is in mid-June to the end of September, after the snow has melted and the road has become accessible to motor vehicles. Generally, the season extends from mid-June through October, but can vary depending on snowpack. Several hundred visitors also arrive in the winter by snowmobile and crosscountry ski. This type of winter use is steadily growing.

Summer visitors arrive primarily by shuttle bus. Visit by private vehicle is not controlled in the spring or fall when the shuttle is not in operation. Visitor use has averaged 143,868 per year over the last three years. Daily visitor loads during the peak period average 2,000. The average length of stay for day users is estimated at four to five hours. Most campers stay an average of two and one half days.

Devils Postpile serves as a trailhead for backpackers using the Pacific Crest and John Muir Trails. These visitors leave their vehicles in the parking lot near the ranger station and spend an average of three days in the backcountry before returning to claim their vehicles. Horseback riders from the Reds Meadow Pack Station and long-distance hikers also pass through Devils Postpile on their way to the backcountry. Approximately 1500 horseback riders use Devils Postpile yearly, with about 1200 taking day trips to Rainbow Falls.

Facilities

Access to Devils Postpile headquarters area is provided by a variable width paved road of approximately 0.34 miles. The narrower sections of the road can be problematic for larger vehicles, including the shuttle buses. The remainder of the park is accessible only by trails.

Unpaved parking accommodating approximately 60 cars is provided at the headquarters area for day visitors and long distance trail users. An additional unpaved parking lot on Forest Service land serves as a trailhead for day hikes to Rainbow Falls and also for long distance trail users. Parking can be a significant problem, particularly when substantial numbers of backpacker vehicles are parked in the area and numerous private vehicles arrive after the shuttle operations have ended for the day. There are about five miles of unpaved trails in Devils Postpile, and two trail bridges across the Middle Fork San Joaquin River. One campground within Devils Postpile provides 21 sites for overnight visitors, and five additional campgrounds are on USFS land within several miles of its boundary.

A small ranger station of approximately 420 square feet provides multiple duty as a minivisitor center, curatorial storage site, and park office. The building was originally located in Yosemite National Park and was moved to Devils Postpile in about 1946.

An administrative area is located near the ranger station, but out of the visitor circulation pattern. Five small, rustic wood-frame cabins provide housing for park employees. A small maintenance building provides some storage and workspace. A fire cache houses fire equipment.

Sequoia and Kings Canyon National Parks

Purpose and Significance

Sequoia and Kings Canyon National Parks protect a variety of landscapes, and biological and cultural resources, in the southern Sierra Nevada of California (Figure B–7). Though juxtaposed, they are two separate national parks created by acts of Congress fifty years apart. Today, both parks are administered as a single unit.

Established September 25, 1890, Sequoia National Park is the second oldest national park in the United States. The campaign to create Sequoia–initiated and executed by San Joaquin Valley residents–focused on the scenic and inspirational values of the region's giant sequoia (California Big Tree *Sequoiadendron giganteum*) groves. The park's original boundaries were drawn to protect what local supporters believed were the largest and best of the unclaimed sequoia groves remaining in the world. One week later, under circumstances that have never been fully explained, Congress tripled the size of the new park, adding to it several sequoia groves already under the nominal control of logging enterprises. Eventually these groves were all preserved. Because the two acts of 1890 established boundaries along section lines, Sequoia National Park included not only giant sequoia forestlands but also considerable tracts comprising both the foothills and High Sierra. The October 1, 1890, act also created four-square-mile General Grant National Park to protect the General Grant Tree and immediately surrounding forest. Since 1890, Sequoia National Park has undergone two major enlargements, both of which added High Sierra lands to the park.

In 1926, Congress added what is known as the Great Western Divide, Kern headwaters, and Sierra Crest regions. This enlargement, which more than doubled the park's acreage, made it clear that Sequoia National Park would not only be a forest park, but also a superlative alpine park. Included within the enlargement areas was Mt. Whitney, the highest mountain in the contiguous United States. In 1978 Congress again enlarged Sequoia National Park, this time adding Mineral King area to park boundaries, previously a part of Sequoia National Forest. Alpine and subalpine in character, Mineral King basin had been proposed by the Forest Service for development as a major downhill ski resort.

Congress added this basin to Sequoia National Park with specific instructions that it be preserved "undeveloped." Please see Appendix A for additional details on legislation and special designations for Sequoia and Kings Canyon National Parks.

Today, the best known and most appreciated features of Sequoia National Park remain the sequoia groves and high country. In recent years, however, a new appreciation has developed which suggests that the park's "buffer lands" are far more important than previously thought, and that the park's greatest value is in its wholeness. These themes are explored in more detail below.

The small General Grant National Park existed unchanged for fifty years. In 1940, however, responding to a two-decade-long political campaign, Congress created Kings Canyon National Park. In addition to incorporating the four square miles of General Grant National Park, and several other adjacent sequoia groves, Kings Canyon National Park featured great glacial canyons and scenic alpine headwaters of the South and Middle Forks of the Kings River. Because the new park contained two separate tracts, one featuring giant sequoia trees and the other canyons and alpine scenery, Kings Canyon's duality was readily apparent from the beginning. In 1940, as a political compromise, the "floors" of the parks two great glacial canyons—Kings Canyon and Tehipite Valley—were left outside its boundaries as possible reservoir sites—this situation was rectified in 1965 when Congress added them to the park.

Description of Resource Values

Excerpted from NPS (1999): Resources Management Plan, Sequoia and Kings Canyon National Parks

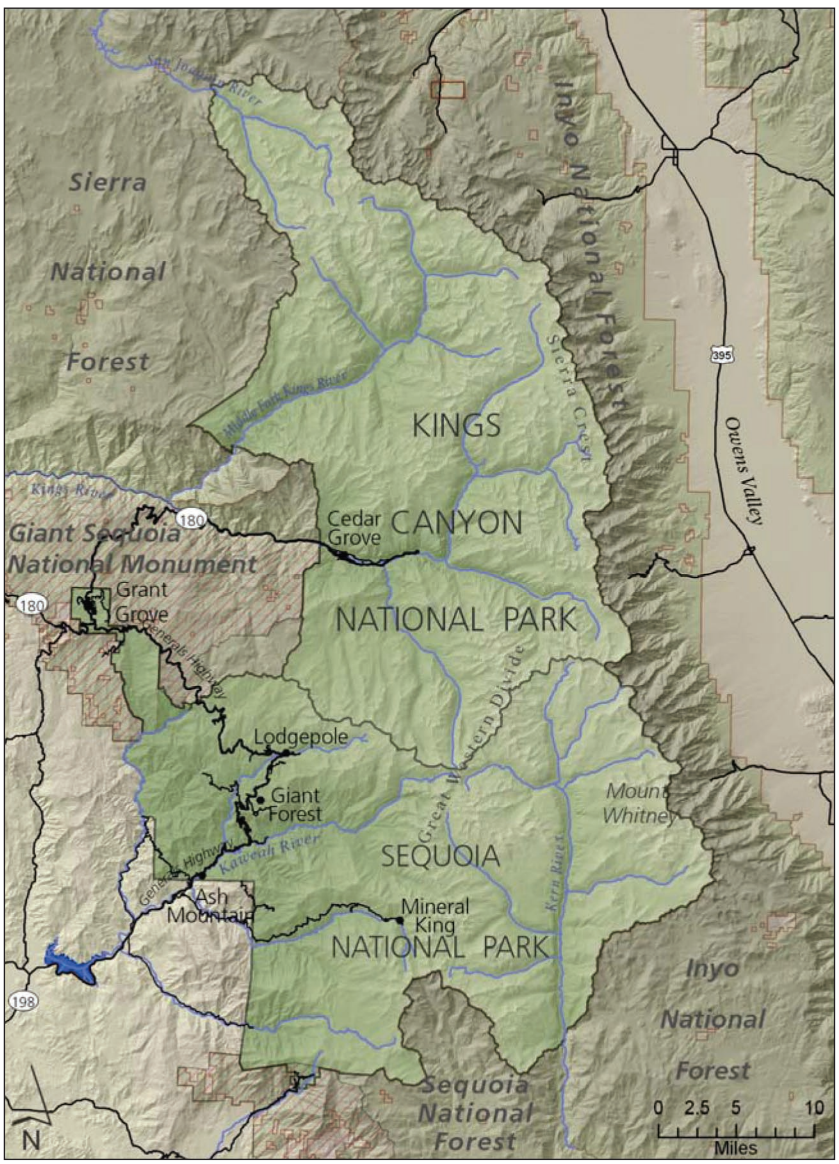


Figure B–7. Sequoia and Kings Canyon National Parks.

Sequoia and Kings Canyon National Parks contain resources of geological, biological, cultural, and sociological value. In addition to national park status, the two reservations have also been designated as a unit of the International Biosphere Preserve Program. In addition, 85% of land within the parks is designated wilderness.

The geological significance of the parks results primarily from the composition and structure of the Sierra Nevada, the highest mountain range in the 48 contiguous states. Geological resources include river-cut canyons more than a mile deep, extensive and spectacular examples of glacial erosion including hundreds of alpine lakes, and several superlative examples of glacially eroded canyons. The most famous of these–Kings Canyon–was once described by John Muir as a "rival of the Yosemite." Within these canyons flows the largest remaining undammed rivers in the Sierra Nevada. Igneous rocks of Mesozoic origins underlie the majority of the two parks, but extensive bands of Paleozoic metamorphic beds also occur. Within the latter, beds of marble are common, as are caves.

The two parks contain over 200 known karst features. Several major cave systems have been located, including Lilburn Cave, which is the most extensive in California (over 17 miles of measured passages). The two parks contain some of the wildest and leastimpacted caves in the United States.

Sequoia and Kings Canyon National Parks also contain biological resources of the great significance. Congress created Sequoia and General Grant National Parks in 1890 expressly to protect the giant sequoia. The General Sherman Tree, growing in Sequoia National Park's Giant Forest, is generally recognized as the largest sequoia and largest living tree on earth. Three other trees in the Giant Forest, and General Grant Tree in Kings Canyon National Park, comprise the list of the world's five largest single organisms (excluding giant fungus, aspen clones, and barrier reefs).

Sequoia trees do not grow continuously through the mixed-conifer forest belt, but rather in geographically limited areas called groves. In the Sierra Nevada, the only present natural home of the sequoias, trees grow in 75 separate groves. While only thirty-seven of these groves are within the two parks, these groves contain more than 65% of all naturally occurring sequoias.

The biological resources of the two parks are not limited to giant sequoia. Extensive tracts of Sierran mixed-conifer forest surround sequoia groves. This forest belt, which generally clothes the mountains at altitudes between 5,000 and 9,000 feet (1,524 and 2,743 m), covers much of the southern Sierra. On surrounding lands, however, the great majority of this forest zone is being managed for multiple use. As a result, Sequoia and Kings Canyon National Parks now contain the largest remaining old growth forest in the southern Sierra. This forest is a very significant resource because its largely pristine nature gives it both a high recreational value and a critical scientific value. Below the conifer forest, in the western portions of the Sierra, are various plant communities and environments that together constitute the foothill region. Kings Canyon contains very little land within this natural zone; but, in Sequoia National Park, lower canyons of several forks of the Kaweah River include extensive foothill lands. This environment, typified by blue oak savanna, chaparral, and oak woodland, covers much of lowland Central California outside the parks. However, very little of this non-park land is receiving any protection. In the Southern Sierra Nevada, the foothill lands of Sequoia National Park are the only foothill tracts currently designated for long-term preservation.

The remainder of Sequoia and Kings Canyon National Parks, most of it above 9,000 feet (2,743 m) elevation, can be described as “high Sierra.” This environment, which covers nearly as much acreage as the other environments combined, is a spectacular land of rugged, ice-sculptured alpine ridges and sparsely wooded lake-jeweled basins. As the heart of the largest wilderness area in California, these lands are of very high recreational and scientific significance.

Preservation of native wildlife within the two parks results naturally from habitat protection that the parks provide and adds yet another level of biological significance. While wildlife found within the parks does not differ significantly from that found naturally on surrounding lands, those lands are mostly undergoing profound change. As a result, the wildlife protection function of the parks is becoming increasingly important. Regional survival of a number of species may ultimately be largely dependent upon the protection the parks provide.

In addition to rich natural diversity, the parks preserve unique cultural and historical records. Eighteen sites or structures within the parks have been listed on the National Register of Historic Places; another six are formally determined to be eligible. Known sites include 312 prehistoric and 110 historic. Site types include prehistoric villages, bedrock mortars and basins, rock art panels, campsites, hunting blinds, cattle and sheep camps, logging camps, sawmills, mines, dams, ranger stations, and CCC-era buildings and structures. The archeological evidence dates back at least five thousand years and indicates a wide-ranging presence throughout the Sierra Nevada of Native American peoples. Local logging, mining, and hydroelectric enterprises, closely related to the formation of the parks, illustrate a particular current of Western settlement and industry. Of the former, the Kaweah Colony, a Bay Area utopian collective which sought to log the sequoias, is unique in representing at once the confidence of industry and the idealism of the early labor movement. Finally, the historical primacy of Sequoia National Park and its unique course of development provide an invaluable and specifically shaded account of the emergence of the preservation ethic and evolution of the National Park Service.

At present, collections contain approximately 320,000 items. Of these, some 250,000 comprise the parks’ archives: 46,000 items are included in the history collection, 12,000 in biology, and 11,000 in archeology. Smaller collections include geology (consisting of around

400 items), ethnology (some 100 items), and paleontology (consisting of 20 examples of fossilized sequoia wood).

The collection contains material from the disciplines of archeology, ethnology, and history and includes documentary material, photographs, fine art, and historic objects.

The sociological values and significance of Sequoia and Kings Canyon National Parks result directly from the quality of natural and cultural resources. The preeminent value of all the parks' resources is that they remain relatively unaffected by modern humans; or in the case of the parks' cultural resources, tell of the historical relationship between humanity and the natural environment. In all descriptions of the parks' resource values, the words "wild" and "natural" appear repeatedly. The value to humanity of the parks' many natural environments is greatly enhanced by their largely unimpaired nature. Both visitors and scientists come to the parks seeking a natural environment unaffected by modern humans. Recent legislation, including the 1978 Mineral King addition to Sequoia, the California Wilderness Act of 1984, the Chimney Rock Wilderness addition, and the addition of the Kings and Kern Rivers to the Federal Wild and Scenic River System, reinforces this theme. The ultimate value of the parks' archaeological resources derives from their ability to help modern humans understand early human's relationship to the natural world.

Yosemite National Park

Purpose and Significance

In 1864, Yosemite Valley and the Mariposa Grove of Big Trees were granted by Act of the U.S. Congress to the State of California for "public use, resort and recreation," and to "be inalienable for all time." Thus, the significance of the area was recognized well before establishment of Yosemite National Park and nearly eight years before Yellowstone was set aside as the world's first national park. Landscape architect Frederick Law Olmsted, designer of New York City's Central Park, provided early direction in managing the Yosemite Grant and saw it as a museum of natural science and native species, and a field of study for art.

In 1906, Congress accepted transfer of the Grant back to the United States, adding it to Yosemite National Park, which had been established in 1890 "to preserve from injury all timber, mineral deposits, natural curiosities or wonders within the park area and to retain them in their natural condition." Several changes to the park boundary were made over the years. In 1984, Yosemite was designated a World Heritage Site.

Approximately 94% of Yosemite's acreage is designated Wilderness. Portions of the Tuolumne River (including the Dana and Lyell Forks), and the main stem and South Fork of the Merced River, are designated National Wild and Scenic Rivers. El Portal Administrative Site west of the park (approximately 566 hectares / 1,400 acres) was established by Act of Congress in 1958, for the purpose of relocating park facilities from within the core park boundary. U.S. Forest Service lands surround the park, and are divided into three national forests: Stanislaus, Toiyabe-Inyo, and Sierra. Please see Appendix A for additional details on legislation and special designations for Yosemite National Park.

The park's exceptional geological, biological, and scenic resources are contained within 308,075 hectares (761,266 acres / 1,189 square miles / 3,079 square km) of scenic wildland, parts of which were first set aside in 1864 (Figure B- 8). Yosemite preserves a portion of the western slope of the central Sierra Nevada.

The region's beauty incited a profound human response that compelled John Muir and others to form the Sierra Club (one of the first private conservation organizations) and prepared the world for the idea of, and desire for, a "national park." This, in itself, is a profound legacy for the world.

> *Nowhere will you see the majestic operations of nature more clearly revealed beside the frailest, most gentle*

and peaceful things. Nearly all the park is a profound solitude. Yet it is full of charming company, full of God's thoughts, a place of peace and safety amid the most exalted grandeur and eager enthusiastic action, a new song, a place of beginnings abounding in first lessons on life, mountain-building, eternal, invincible, unbreakable order; with sermons in stones, storms, trees, flowers, and animals brimful of humanity.

(Muir 1901)

Frederick Law Olmsted, considered to be America's premier landscape architect, aided this quest for a "public park" through his preliminary report on the Yosemite Valley and the Mariposa Big Tree Grove. This report encapsulated the character and value of the Yosemite region:

No photograph or series of photographs, no painting ever prepare a visitor so that he is not taken by surprise, for could the scenes be faithfully represented the visitor is affected not only by that upon which his eye is at any moment fixed, but by all that with which on every side is associated, and of which it is seen only as an inherent part.

[T]he union of deepest sublimity with the deepest beauty of nature, not in one feature or another, not in one part of scene or another, not in any landscape that can be framed by itself, but all around and wherever the visitor goes, constitutes the 'Yo Semite', the greatest glory of nature.

(Olmstead 1865)

Description of Resource Values

Yosemite's landscape comprises a wide range of elevations, from its semi-arid foothills to its snowcapped crests—from 610 meters in El Portal, to 3,998 meters in height at Mount Lyell (range 2,000 to 13,123 feet). The park can be further divided into five major vegetative zones: chaparral/oak woodland, lower montane, upper montane, subalpine, and alpine. In addition to these impressive ecosystems, it includes three groves of Giant Sequoias and glacier-carved Yosemite Valley–with its abundance of waterfalls, cliffs, and extraordinary rock formations.

The climate of Yosemite, like the entire central Sierra Nevada, is Mediterranean—hot, dry summers and cool, moist winters. The foothills and lower slopes are semiarid, and the higher peaks and crests are also relatively dry; the majority of rain and snow falls at the middle elevations between approximately 1,220 and 2,743 meters (4,000 to 9,000 feet).

Dotted in among the forests, meadows, and broad expanses of rock are over 3,000 water bodies—each a reminder of the glaciers that gourged many basins in their slow, powerful journey. These sparkling jewels are located in the upper reaches of canyons and glacial amphitheatres around the peaks,

Figure B–8. Yosemite National Park.

primarily in the subalpine and alpine regions. Glacial meadows are spread over the filled-in basins of vanished lakes. In the Park's high country, the most extensive and well known meadows are the Tuolumne Meadows.

Tuolumne Meadows is the largest subalpine meadow complex in the Sierra. In general, however, Yosemite is heavily forested. The size of individual trees and the diversity of species is due to climatic variation and topography that influence distribution of soils and moisture. The Park contains three giant Sequoia (*Sequoiadendron giganteum*) groves, though they do not compare to the number and grandeur of those found in Sequoia and Kings Canyon National Parks.

The geology of Yosemite is characterized by granitic rocks and remnants of older rock (Huber 1989), formed during three intrusions dating from 200 to 85 millions years ago.

In the early Tertiary period, 40 to 60 million years ago, the geologic environment of the Sierra Nevada region was lower in elevation, with a gently rolling upland surface. The Merced River flowed at a gentle gradient westward through a broad river valley.

About 10 million years ago, the Sierra Nevada was uplifted and then tilted to form its relatively gentle western slopes and the more dramatic, steep eastern slopes. The uplift increased the flow gradients, resulting in deep, narrow canyons.

Subsequent uplifting and erosion created the two major drainage basins: Merced and Tuolumne, both National Wild and Scenic Rivers. The Merced watershed begins in the Park's southern peaks, primarily in the Clark range. The South Fork of the Merced flows through the area of Wawona (a Miwok word which means "big tree", referring to the giant Sequoia), uniting with the main stem west of the Park boundary. The main stem of the Merced, growing from numerous tributaries, fills up lake basins such as Washburn Lake and Merced Lake before running through Yosemite Valley and the steep downstream Merced Canyon. The Park's largest river, the Tuolumne, drains the entire northern portion of the Park. Originating at Mount Lyell glacier (the second largest extant glacier in the Sierra Nevada), the Tuolumne flows through Lyell Canyon, Tuolumne Meadows, Glen Aulin, the Grand Canyon of the Tuolumne, and finally merges with the water of the Hetch Hetchy reservoir on the Park's western boundary (an artificial lake impounded by a dam, part of San Francisco's water supply). Mount Lyell, the highest peak in Yosemite (3,998 meters /13,123 feet), occupies the apex of the range and drains into both Tuolumne and Merced watersheds.

About 1 million years ago, snow and ice accumulated, forming glaciers at the higher alpine elevations that began to move westward down the river valleys. The whole Sierra Nevada range was, at one time, covered with glaciers that furrowed canyons 610 to 1,829 meters (2,000 to 6,000 feet) deep. Ice thickness within Yosemite Valley may have reached 4,000 feet (1,219 meters) during the early glacial episode. Downslope movement of the ice masses cut and sculpted the U-shaped valley evident today. After the last glacier receded from the valley about 15,000 years ago, a lake referred to as Lake Yosemite was formed behind a "dam" of depositional materials left behind. More than 1,000 feet (914 meters) of glacial and stream sediments now comprise the floor of Yosemite Valley, covering glacially disturbed granitic rock (Huber 1989).

Such glacial action resulted in the final stripping of the metamorphic overlayer, leaving behind textbook-perfect glacial features for which Yosemite is known: domes, moraines, sheer rock walls, and hanging valleys. An equally rare and striking glacial phenomenon is "glacial polish" or "pavement." The glacial pavements are so young that erosive weathering has barely marred their brilliant beauty.

> *". . . Every peak, ridge, dome, canyon, lake basin, garden, forest, and stream testifies to the existence and modes of action of . . . scenerymaking ice"*
>
> (Muir, undated)

Yosemite Valley is the "world's most renowned example of a [glacially carved] valley" (Hill 1975), itself a single feature of beauty and fame that dramatically displays the varied rock forms created by glaciers. In no other canyon or valley is "magnitude, beauty, and accessibility so ideally combined as in Yosemite" (California Geological Survey 1869). Eight different granitic rock types occur in Yosemite Valley alone.

However, Yosemite Valley is not the only valley of note within the Park. A dozen miles to the north is the Grand Canyon of the Tuolumne River—a prodigious gash which exceeds Yosemite Valley in length and depth—which opens into Hetch Hetchy Valley.

A feature not restricted to Yosemite Valley—although many of the largest ones occur there—are great granite domes. Domes are rare on this planet and "the Yosemite region contains a greater and more varied assemblage of [domes and related] distinctive forms than any other area of similar extent in the Sierra Nevada or, perhaps, on Earth" (Matthes 1950).

However impressive Yosemite's geologic features are, the Park's waterfalls are often the natural feature most remembered by those who visit. There are two types of falls in Yosemite—those that leap free pouring from the lips of hanging valleys, and those that cascade in stair-step fashion in a canyon. "No where in the world are there waterfalls of such variety within a single area as those that leap into Yosemite Valley in the spring and early summer" (Schaffer 1978). The "waterfalls of the Yosemite region are relatively slender, resembling shimmering veils of ribbons fluttering from the cliffs" (Matthes 1950). Among Yosemite's waterfalls are some of the tallest and most spectacular of the "free-leaping" type which is relatively rare in nature. Yosemite has two of the world's ten tallest-known waterfalls (Yosemite and Ribbon Falls). Angel Falls in Venezuela at 979 meters (3,212 feet) is the tallest in the world; Yosemite Falls, at 739 meters (2,425 feet), is the tallest in the park.

Overview of Biological Diversity, Ecological Integrity, and Resource Issues

Humans have lived and sustained themselves in the region for at least 9,000 years and are part of the Sierra Nevada ecosystem. Indigenous populations were widely distributed throughout the area at the time of Euro-American immigrations. Archeological evidence indicates that for more than 3,000 years American Indians practiced localized burning, harvesting, pruning, irrigation, and vegetation thinning. Immigration of Euro-American settlers in the mid-1800s began a period of increasingly intense resource use and settlement (SNEP 1996). As in Sequoia and Kings Canyon National Parks, Yosemite fire history studies document a decline in frequent, widespread fires by the mid 1800s (Swetnam 1993, Swetnam et al. 1998). This disruption of fire regime was concommitant to introduction of large numbers of sheep and other livestock into higher elevation forests of the Sierra Nevada during and following the drought of the early 1860s (Swetnam et al. 1998).

Still, Yosemite National Park remains one of the largest and least-fragmented habitat blocks in the Sierra Nevada, and supports a diverse and abundant assemblage of plants and wildlife. As stated above, "[f]ew areas in the United States have more variety of native flora and fauna than the Sierra slopes" (Shaffer 1978). Its importance in protecting the long-term survival of certain species and overall biodiversity of vegetation and wildlife in the Sierra Nevada was recognized in congressional reports prepared as part of the Sierra Nevada Ecosystem Project (SNEP 1996). Yosemite possesses five of the seven recognized life-zones that occur in the United States. "Few areas in the United States have more variety of native flora and fauna than the Sierra slopes" (Shaffer 1978).

Today, most plant communities in Yosemite and other national park units within the Sierra Nevada Network are fairly intact as compared to similar non-Wilderness areas outside park boundaries. Much of this "pristine" quality can be attributed to relatively low levels of historic and/or recent human-caused alteration, and lack of disruption of natural processes. Notable exception to this is the displacement by introduced

Eurasian species of the native herbaceous understory of the meadows of Yosemite Valley and foothill savannas and woodlands of Sequoia National Park. However, impacts to plant communities, species, and individuals can be found throughout all parks. Past logging and grazing continue to affect hydrology and soils, and thus vegetation, in many areas of the parks, including parts of both subalpine and alpine environments.

The park's ecosystems depend upon dynamic natural processes. There exist everchanging environments resulting from the presence or absence of fire, alterations in watersheds, and variations in climate.

More recent manipulations of the environment have resulted in alterations in vegetation in many locales. These forcing agents include suppression of natural fire frequencies, local water diversions or water impoundments, and development of infrastructure throughout non-Wilderness portions of the parks. In addition, changes in these natural processes of fire and flooding have resulted in changes in effects of re-introduced fire or floods, including sometimes greater fire intensities and severities in all parks, and depth of flooding, scour, and depositional patterns in Yosemite. Finally, the level of recreational use today in the most popular areas of the parks, although quite localized, has led to trampling, loss of vegetative cover, and increased susceptibility to the introduction of non-native plant species. The latter are brought in on vehicles, in construction and maintenance materials, as well as on the feet and hooves of visitors and their animals. All of these factors have lead to identification of management issues requiring far better inventory and monitoring data than presently exist.

Riparian and wetland areas contain important plant and animal habitat, yet they receive levels of recreational use out of proportion to their occurrence. Trampling and streambank damage associated with this use introduce disturbance factors that favor exotic plant establishment in areas especially susceptible to non-native intruders, further degrading this critical ecotonal habitat between aquatic and upland terrain.

In some park habitats—particularly chaparral, hardwood forest and woodland, and mixed-conifer—a long history of fire suppression has affected the natural structure and succession of plant communities, which has in turn affected habitat quality for both plants and wildlife. In some cases, this has also led to fires of unnaturally high intensity, which have drastically altered habitats for many years to come. In others, gaps that would otherwise form in conifer forest from natural fires (and thereby provide habitat for "forage" species) have been greatly reduced. Decades of fire suppression disrupted competitive balance between non-native and native plant species, and jeopardized the viability of some fire-dependent species. Yosemite National Park has used prescribed fire since 1970 and monitored lightning-ignited fires since 1972 to reduce fuels and return fire to the landscape (van Wagtendonk 1977). Fire is a profoundly important ecological process in these systems, but both prescribed and wildland fires can create conditions that promote exotic plant establishment. On the other hand, fire suppression activities contribute to introduction of exotic plant propagules while creating conditions for their establishment.

Air pollution, especially in the southern Sierra Nevada, has affected vitality of some plant species studied, and may be extensively altering competitive balance and overall productivity of some plant communities. Global climate change, if it takes place as predicted, is expected to lead to striking changes in distribution, persistence, and character of many plant communities throughout their range.

Vegetation

Major vegetation zones in Yosemite form readily apparent, large-scale, north-south elevational bands along the axis of the Sierra Nevada. Major east-west watersheds that dissect the park into steep canyons form a secondary pattern of vegetation. Yosemite National Park supports five major vegetation zones: chaparral/oak woodland, lower montane, upper montane, subalpine, and alpine. The park is rich in plant diversity. Of California's 7,000 plant species, about 50% occur in the Sierra Nevada—more than 20% within Yosemite alone.

To date, 1,561 plant taxa are thought to occur within park boundaries. Documented records of, or suitable habitat for, approximately 164 special-status plant species exist in the park. As a group, Sierra Nevada plants are most at risk where habitat has been reduced or altered. In some areas, rare local geologic formations and associated unique soils have led to evolution of ensembles of plant species restricted to these uncommon habitats. This is true in the El Portal area, where a number of state-listed rare species are sustained in a unique contact zone of metamorphic and granitic rock.

Although moderately extensive plot networks in Kings Canyon, Sequoia, and Yosemite have provided good information on distribution and habitat affinities of common species of plants, little is known regarding distribution of rare and special-status plant species (beyond some opportunistic surveys conducted during the 1980s and some work currently being conducted). Information on current population trends is non-existent, making impossible any comparisons of such information to trends on adjacent lands with differing management strategies.

Little-to-nothing is known about the diversity, distribution, and abundance of nonvascular plants within the park.

Wildlife

Wildlife populations in Sierra Nevada Network parks, as a whole, are thought to be relatively intact compared to other areas of the Sierra Nevada where human activities such as hunting, logging, grazing, fire suppression, and extensive development have led to widespread degradation, particularly in lower elevations outside designated wilderness.

In the parks, however, some human activities and development have affected wildlife and habitats. The most notable example is the inundation of Hetch Hetchy Valley by construction of O'Shaughnessy Dam across the Tuolumne River in Yosemite, destroying riparian, oak woodland, and wetland habitats that comprised a substantial portion of all bottomland winter habitat in that park. Similar habitats survive in Yosemite Valley, but roads and dense development in the east end of the Valley have eliminated or fragmented them; high levels of human activity from millions of visitors result in disturbance to wildlife. In Kings Canyon, Sequoia, and Yosemite, local areas of montane to subalpine habitats have been developed in ways detrimental to some native animals, but these represent a relatively minor proportion of available habitat.

To date, faunal composition of Yosemite is as follows:

- 82 native mammals (seventeen of those are bats—nine of which are either federal "Species of Concern" or State "Species of Special Concern").
- 273 birds (1 is listed as federally threatened; 13 are either federal "Species of Concern" or State "Species of Special Concern")
- 24 reptiles (2 are both federal "Species of Concern" and State "Species of Special Concern")
- 14 amphibians (5 are both federal "Species of Concern" and State "Species of Special Concern")
- 15 fish species (five of which are non-native)

For some species we know the reason(s) for decline; for others, we do not. For example, Pacific fishers (*Martes pennanti pacifica*) are present in very low numbers in the park.

Road-kills and low numbers of an important prey species (porcupine, *Erethizon dorsatum*) may be explanations, but not enough information exists to determine causative factors. Bighorn sheep (*Ovis canadensis sierrae*) (State-endangered; being considered for federal listing) formerly populated the Sierra crest, but have been reduced to several remnant populations—none of which regularly occur in Yosemite. Reasons for their initial decline are unknown, though today they are frequently depredated by mountain lions. Grizzly bears (*Ursus horribilis*) once occurred in the park, but were extirpated from the state by the early 20th century. Black bears (*Ursus americanus*) are abundant in the park and are often involved in conflicts with humans that result in property damage, injuries to humans, and the necessity of euthanizing black bears that present a clear threat.

Introduction of non-native species has affected some native wildlife species in the parks. Introduction of several species of salmon fish to high-elevation lakes and streams that were naturally fishless radically altered faunal communities of those waters and is suspected to be the primary cause of disappearance of mountain yellow-legged frogs (*Rana muscosa*) from wide areas of its former range throughout the Sierra Nevada.

Population declines of Yosemite toads (*Bufo canorus*)—and complete disappearance of foothill yellow-legged frogs (*Rana boylei*)—may also be at least partially due to nonnative species. Bullfrogs (*Rana catesbeiana*) are present in Yosemite Valley, several lakes in the north part of Yosemite, and some foothill portions of Sequoia where foothill yellow-legged frogs, or California red-legged frogs (*Rana aurora draytoni*), a federal Threatened species, once existed. Bullfrogs also prey on western pond turtles found in Sequoia. Brown-headed cowbirds (*Molothrus ater*), recent arrivals in the Sierra Nevada, flourish at stables, campgrounds, and residential areas of the parks, affecting native bird species through nest parasitism.

Other adverse effects on park wildlife originate outside park boundaries. For example, Willow Flycatchers (*Empidonax traillii*), a federal Threatened species, have become recently rare in the parks, although their favored habitat, meadows with willow thickets, is largely intact. Sierra-wide decimation of Willow Flycatchers, primarily from grazing and clearing of habitat—and perhaps cowbird parasitism—has affected numbers of this species in the parks as well by reducing regional population size to such a low number that it is difficult for park populations to be self-sustaining. Such regional effects on habitat likely affect a wide range of species in parks that are migratory or rely on immigration of individuals from adjacent areas.

One federal Endangered invertebrate is known to occur within the park (Valley elderberry longhorn beetle (Desmocerus californicus). Little-to-nothing is known about the diversity, distribution, and abundance of most other invertebrates within Yosemite.

Facilities

Yosemite National Park has major developed areas in Yosemite Valley, Wawona, and Tuoloumne Meadows. Smaller developed areas include Aspen Meadows, Crane Flat, Hodgdon Meadow, Foresta, White Wolf, Porcupine Flat, Tioga Pass, Hetch Hetchy, South Entrance, Arch Rock and Glacier Point. Development zones, managed to provide roads and facilities to serve visitors and the management of the park, comprise approximately 13,000 acres, or 1.7% of the park. El Portal and Yosemite West abut the park.

In Yosemite Valley are Yosemite Village, Yosemite Lodge/Camp 4, Ahwahnee, Curry Village, Housekeeping Camp, the Campground complex, and Happy Isles. North and Southside Drives run from the west end of the valley at Pohono, east and looping to connect all developed areas in the east end of the valley. Infrastructure follows similar paths, and in some instances contributes to such problems as the draining of meadows.

Wawona is located along the South Entrance Road. This community of approximately 300 homes and vacation homes is served by a network of roads that branch from the Chilnualna Falls Road, which parallels a reach of the South Fork of the Merced River. Wawona Hotel and Pioneer Village are the major visitor services.

Tuolumne Meadows includes Tuolumne Lodge, Tuolumne Meadows Campground, parking and logistical support facilities for various day and overnight visitor activities. The Tioga

Road follows the edge of Tuolumne Meadows, a fragile subalpine meadow, and in some locations contributes to conifer invasion and other impacts.

There are four main park entrances, each serving a major road corridor: Tioga Pass, along the Tioga Road; Big Oak Flat, along the Big Oak Flat Road; Arch Rock, along the All- Weather Highway from El Portal; and the South Entrance, along the south entrance road (Mariposa Grove Road and the Glacier Point Road begin along this road).

References

Anderson, M. K., and M. J. Moratto. 1996. Native-American land use practices and ecological impacts. Sierra Nevada Ecosystem Project Report to Congress, Vol II. Assesments and Scientific Basis for Management Options Davis: University of California Centers for Water and Wildland Resources.

Anderson, R. S., and S. J. Smith. 1997. Sedimentary record of fire in montane meadows, Sierra Nevada, California, USA: A preliminary assessment. Pages 313-327 *In* J. S. Clark, H. Cachier, J. G. Goldammer, and B. Stocks, editors. Sediment Records of Biomass Burning and Global Change. NATA ASI series, Springer-Verlag, Berlin.

Arnett, M., and S. Haultain. 2004. Vascular plants of Devils Postpile National Monument, Final report to Sierra Nevada Inventory & Monitoring program. National Park Service, Three Rivers, CA.

Bateman, P. C. 1992. Plutonism in the central part of the Sierra Nevada batholith, California. U.S. Geological Survey Paper 1483.

Bateman, P. C., L. D. Clark, N. K. Huber, J. G. Moore, and C. D. Rinehart. 1963. The Sierra Nevada batholith: A synthesis of recent work across the central part. U.S. Geological Survey Paper 414-D.

Biswell, H. H. 1961. The big trees and fire. *National Parks Magazine* **35**:11-14.

Brown, P. M., M. K. Hughes, C. H. Baisan, T. W. Swetnam, and A. C. Caprio. 1992. Giant sequoia ring width chronologies from the central Sierra Nevada, California. *Tree-Ring Bulletin* **52**:1-14.

Caprio, A. C. 2000. Analysis done at Sequoia and Kings Canyon National Parks.

Caprio, A. C., C. Conover, M. Keifer, and P. Lineback. 2002. Fire management and GIS: A framework for identifying and prioritizing fire planning needs. N. G. Sugihara and M. E. Morales. Proceedings of the symposium: Fire in California ecosystems: Integrating ecology, prevention and management, San Diego, CA, Nov. 17-20, 1997. Vol. 1.

Caprio, A. C., and D. M. Graber. 2000. Returning fire to the mountains: Can we successfully restore the ecological role of pre-Euroamerican fire regimes to the Sierra Nevada? D. N. Cole, S. F. McCool, W. T. Borrie, and J. O'Loughlin. Proceedings: Wilderness Science in a Time of Change. Wilderness Ecosystems, Threats, and Management, Missoula, MT and Ogden, UT, May 23-27, 1999. Vol. RMRS-P-15-VOL-5.

Caprio, A. C., and P. Lineback. 2002. Pre-twentieth century fire history of Sequoia and Kings Canyon National Parks: A review and evaluation of our knowledge. N. G. Sugihara, M. E. Morales, and T. J. Morales. Proceedings of the Symposium: Fire in California Ecosystems: Integrating Ecology, Prevention and Management, San Diego, CA, Nov.17-20, 1997. Vol. 1.

Caprio, A. C., and T. W. Swetnam. 1993. Fire history and fire climatology in the southern and central Sierra Nevada: Progress Report 1992/93 to National Park Service Global Change Program, Southern and Central Sierra Nevada Biogeographical Area. Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ.

Caprio, A. C., and T. W. Swetnam. 1994. Fire history and fire climatology in the southern and central Sierra Nevada: Progress Report 1993/94 to National Park Service Global Change Program, Southern and Central Sierra Nevada Biogeographical Area. Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ.

Caprio, A. C., and T. W. Swetnam. 1995. Historic fire regimes along an elevational gradient on the west slope of the Sierra Nevada, California. Pages 173-179 *In* J. K. Brown, R. W. Mutch, C. W. Spoon, and R. H. Wakimoto, editors. Proceedings of a Symposium on Fire in Wilderness and Park Management. USDA Forest Service Gen. Tech. Rep. INT-GRT-320.

Chang, C. 1996. Ecosystem responses to fire and variations in fire regimes. Pages 1071- 1099 *In* Sierra Nevada Ecosystem Project, Final Report to Congress, Vol. II, Assessments and Scientific Basis for Management Options. University of California, Centers for Water and Wildlands Resources, Davis, CA.

Clow, D. W., and K. R. Collum. 1986. Geology of the volcanic rocks at Devils Postpile, California. *Journal of Natural Sciences* **1**:18-21.

Clow, D. W., M. A. Mast, and D. H. Campbell. 1996. Controls on surface water chemistry in the upper Merced River basin, Yosemite National Park, California. *Hydrological Processes* **10**:727-746.

Davis, O. K., and M. J. Moratto. 1988. Evidence for a warm dry early Holocene in the western Sierra Nevada of California: Pollen and plant macrofossil analysis of Dinkey and Exchequer Meadows. *Madrono* **35**:132-149.

Despain, J. 2003. Hidden beneath the mountains: The caves of Sequoia and Kings Canyon National Parks. Cave Research Foundation, Inc., Dayton, OH.

Gill, A. M. 1975. Fire and the Australian flora: A review. *Australian Forestry* **38**:4-25.

Graber, D. M. 1996. Status of terrestrial vertebrates. Pages 709-734 *In* Sierra Nevada Ecosystem Project: Final Report to Congress, vol. II, Assessments and Scientific Basis for Management Options. University of California, Centers for Water and Wildland Resources, Davis, CA.

Graber, D. M., S. A. Haultain, J. E. Fessenden, S. D. Veirs, T. J. Stohlgren, and C. M. Schonewald-Cox. 1993. Conducting a biological survey: A case study from Sequoia and Kings Canyon National Parks. Fourth Conference on Research in California's National Parks: National Park Service.

Hartesveldt, R. J., and H. T. Harvey. 1967. The fire ecology of sequoia regeneration. Tall Timbers Fire Ecology Conference Proceedings. Vol. 7.

Harvey, H. T., H. S. Shellhammer, and R. E. Stecker. 1980. Giant Sequoia Ecology: Fire and Reproduction. Scientific Monograph Series USDI NPS, Washington, D.C.

Heinselman, M. L. 1981. Fire intensity and frequency as factors in the distribution and structure of northern ecosystems. Pages 7-57 *In* T. M. Mooney, T. M. Bonnicksen, N. L. Christensen, J. E. Lotan, and W. A. Reiners, editors. Proceedings of the conference: Fire regimes and ecosystem properties. USDA Forest Service, Honolulu, HI.

Holmquist, J. G., and J. M. Schmidt-Gengenbach. 2005. Interim report: A pilot study on the efficacy of invertebrates as indicators of meadow change in Sierra Nevada Network parks. White Mountain Research Institute, University of California.

Huber, N. K. 1987. The geologic story of Yosemite National Park. USGS Bulletin 1595.

Huber, N. K., P. C. Bateman, and C. Wahrhaftig. 1989. Geologic map of Yosemite National Park and vicinity, California. USGS Map I-1874.

Kattelmann, R. 1996. Hydrology and Water Resources. In Sierra Nevada Ecosystem Project, Davis, CA.

Keifer, M. 1991. Age structure and fire disturbance in southern Sierra Nevada subalpine forests. MS Thesis. University of Arizona, Tucson, AZ.

Kilgore, B. M. 1971. The role of fire in managing red fir forests. *Transcript North America Wildlife Natural Research Conference* **35**:405-416.

Kilgore, B. M. 1972. Fire's role in a Sequoia Forest. *Naturalist* **23**:26-37.

Kilgore, B. M. 1973. The ecological role of fire in Sierran conifer forests: Its application to national park management. *Quaternary Research* **3**:496-513.

Kilgore, B. M., and D. Taylor. 1979. Fire history of a sequoia mixed-conifer forest. *Ecology* **60**:129-142.

Knapp, R. A., C. P. Hawkings, J. Ladau, and J. G. McClory. 2005. Fauna of Yosemite National Park lakes has low resistance but high resilience to fish introductions. *Ecological Applications* **15**:835-847.

Krejca, J. in progress. Inventory of karst fauna in Kings Canyon, Sequoia and Yosemite National Parks. Contract No. P8558602608, Zara Environmental LLC, Buda, Texas.

Lindgren, W. 1911. The tertiary gravels of the Sierra Nevada of California. U.S. Geological Survey Professional Paper 73.

Matthes, F. E. 1960. Reconnaissance of the geomorphology and glacial geology of the San Joaquin basin, Sierra Nevada, California. U.S. Geological Survey Professional Paper 329.

Matthews, K. R., R. A. Knapp, and K. L. Pope. 2002. Garter snake distributions in high elevation aquatic ecosystems: Is there a link with declining amphibian populations and nonnative trout introductions? *Journal of Herpetology* **36**:16-22.

McBride, J. R., and D. F. Jacobs. 1980. Land use and fire history in the mountains of southern California. M. A. Stokes and J. H. Dieterich. Fire History Workshop, Tucson, AZ. Vol. GTR-RM.

McClaren, M. P., and J. W. Bartolome. 1989. Fire-related recruitment in stagnant *Quercus douglasii* populations. *Canadian Journal of Forest Research* **19**:580-585.

Mensing, S. A. 1992. The impact of European settlement on blue oak (*Quercus douglasii*) regeneration and recruitment in the Tehachapi Mountains, California. *Madrono* **39**:36-46.

Moore, P. 2003. Special status vascular plant list for Yosemite National Park: Interim Report. WERC-USGS Yosemite Field Station report to Sierra Nevada Network Inventory and Monitoring Program.

National Park Service. 2001. Director's Order #47: Soundscape preservation and noise management. National Park Service.

Neitlich, P. 2004. Personal communication (NPS Ecologist/Lichen Specialist, Alaska Region).

Norris, D. H., and D. A. Brennan. 1982. Sensitive plant species of Sequoia and Kings Canyon National Parks. Co-operative National Park Resources Study Technical Report No. 8.

Norris, D. H., and J. R. Shevock. 2004a. Contributions toward a bryoflora of California I: A specimen-based catalogue of mosses. *Madrono* **51**:1-131.

Norris, D. H., and J. R. Shevock. 2004b. Contributions toward a bryoflora of California II: A key to the mosses. *Madrono* **51**:132-269.

Pierson, E. D., and W. E. Rainey. 2003. Inventory of bat species in Kings Canyon and Sequoia National Parks. Report on 2002 surveys to Sierra Nevada Network Inventory and Monitoring Program, Berkeley, CA.

Pierson, E. D., W. E. Rainey, and C. J. Corben. 2001. Seasonal patterns of bat distribution along an altitudinal gradient in the Sierra Nevada. Report to California State University at Sacramento Foundation, Yosemite Association and Yosemite Fund.

Pitcher, D. 1981. The ecological effects of fire on stand structure and fuel dynamics in red fire forests of Mineral King, Sequoia National Park, California. M.S. Thesis. UC Berkeley.

Pitcher, D. 1987. Fire history and age structure in red fir forests of Sequoia National Park, California. *Canadian Journal of Forest Research* **17**:582-587.

Roper Wickstrom, K. C. 1992. A study of high altitude obsidian distribution in the southern Sierra Nevada, California. Sonoma State University, Petaluma, CA.

Sheppard, P. R. 1984. Fire regime of the lodgepole pine (*Pinus contorta* var. *murrayana*) forests of the Mt. San Jacinto State Park Wilderness, California. M.S. Thesis. Cornell University, Ithaca, NY.

Shevock, J. R. 2002. Personal communication. (California CESU coordinator, bryologist).

Shevock, J. R. In progress. Sierra Nevada Bryophyte Inventory.

Skinner, C. N., and C. Chang. 1996. Fire regimes, past and present. Sierra Nevada ecosystem project, final report to congress: Status of the Sierra Nevada, vol. II, assessments and scientific basis for management options.

Smith, D. W. 1980. A taxonomic survey of the macrolichens of Sequoia and Kings Canyon National Parks. San Francisco State University.

Smith, S. J., and R. S. Anderson. 1992. Late Wisconsin paleoecologic record from Swamp Lake, Yosemite National Park, California. *Quaternary Research* **38**:91–102.

SNEP. 1996a. Sierra Nevada Ecosystem Project: Final Report to Congress. 36 & 37, University of California, Center for Water and Wildlands Resources, Davis, California, USA.

SNEP. 1996b. Sierra Nevada Ecosystem Project: Final Report to Congress—Summary. University of California, Centers for Water and Wildland Resources, Davis, CA.

State Water Resources Control Board. 2002. 2002 California 305(b) report. California Environmental Protection Agency State Water Resources Control Board.

Steen, A. J. 1988. Contributions to the bryophyte flora of Sequoia and Kings Canyon National Parks No. 2, including all species determined to date. National Park Service.

Stephens, S. L. 1997. Fire history of a mixed conifer oak-pine forest in the foothills of the Sierra Nevada, El Dorado County, California. N. H. Pillsbury, J. Verner, and W. D. Tietje. Proceedings of a Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, San Luis Obispo, CA, March 19-22, 1996. Vol. PSW-GTR-160.

Stephenson, N. L. 1988. Climatic control of vegetation distribution: The role of the water balance with examples from North America and Sequoia National Park, California. Dissertation. Cornell University, Ithaca, NY.

Stephenson, N. L., D. J. Parsons, and T. W. Swetnam. 1991. Natural fire to the sequoiamixed conifer forest: Should intense fire play a role. Poceedings 17th Tall Timbers Fire Ecology Conference: High Intensity Fire in Wildlands: Management Challenges and Options, Tall Timbers Research Station, Tallahassee, Florida, May 18-21, 1989.

Stoddard, J. L. 1987. Microcrustacean communities of high-elevation lakes in the Sierra Nevada, California. *Journal of Plankton Research* **9**:631-650.

Stokes, J. a. 2003. Special-status vascular plant lists and survey strategy for the Sierra Nevada Network Parks. Prepared for Sequoia and Kings Canyon National Parks. J&S 00-430, Sacramento, CA.

Swetnam, T. W. 1993. Fire history and climate-change in Giant Sequoia Groves. *Science* **262**:885-889.

Swetnam, T. W., C. H. Baisan, A. C. Caprio, R. Touchan, and P. M. Brown. 1992. Treering reconstruction of giant sequoia fire regimes. Final report to Sequoia, Kings Canyon and Yosemite National Parks Laboratory of Tree-Ring Research, Tucson, AZ.

Swetnam, T. W., C. H. Baisan, K. Morino, and A. C. Caprio. 1998. Fire history along elevational transects in the Sierra Nevada, California. Final report to Sierra Nevada Global Change Research Program Sequoia and Kings Canyon National Parks, USGS BRD Sequioa and Kings Canyon, and Yosemite Field Stations.

Swetnam, T. W., R. Touchan, C. H. Baisan, A. C. Caprio, and P. M. Brown. 1990. Giant sequoia fire history in Mariposa Grove, Yosemite National Park. Yosemite Centennial Symposium: Natural Areas and Yosemite, Prospects for the Future, Concord, CA, 1991.

Taskey, R. D. 1995. Soil Survey of High Sierra area, California. U.S. Department of Agriculture, USFS, Pacific Southwest Research Station, CA.

van Wagtendonk, J. W., K. A. van Wagtendonk, J. B. Meyer, and K. J. Paintner. 2002. The use of geographic information for fire management planning in Yosemite National Park. *The George Wright Forum* **19**:19-39.

Warner, T. E. 1980. Vegetation management plan for the Grant Tree area. Sequoia and Kings Canyon National Parks Management Report.

Weaver, H. 1967. Fire and its relationship to ponderosa pine. Proc. Tall Timbers Fire Ecology Conference. Vol. 7.

Weaver, H. 1974. Effects of fire on temperate forests: Western United States. Pages 542 *In* T. T. Kozlowski and C. E. Ahlgren, editors. Fire and Ecosystems. Academic Press.

Wetmore, C. M. 1986. Lichens and air quality in Sequoia and Kings Canyon National Parks. Contract No. CX 0001-2-0034, Denver, CO.

Whitney, J. D. 1880. The auriferous gravels of the Sierra Nevada of California. Harvard College Musuem of Comparative Zoology Memoir **6**.

Yount, J., and D. D. La Pointe. 1997. Glaciation, Faulting, and Volcanism in the Southern Lake Tahoe Basin. Pages 34-56 *In* B. Dillet, L. Ames, L. Gaskin, and W. Kortemeier, editors. Where the Sierra Nevada Meets the Basin and Range.